



BEEES AND
BEE-KEEPING
Scientific and Practical



Vol. I. - Scientific

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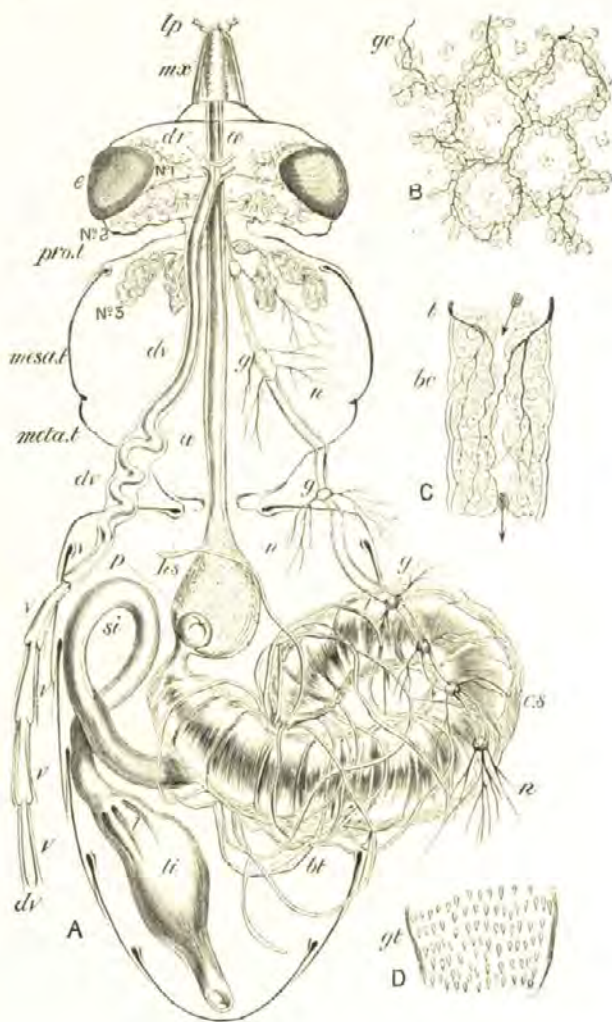
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VOL. I.

BEES AND BEE-KEEPING.

SCIENTIFIC AND PRACTICAL.





DIGESTIVE SYSTEM OF BEE (Magnified Ten times).

- A. Horizontal Section of Body—*lp*, Labial Palpus; *mx*, Maxilla; *v*, Eye; *dv*, *dv*, Dorsal Vessel; *v*, Ventricles of the same; No. 1, No. 2, No. 3, Salivary Gland Systems, 1, 2, 3; *oe*, Oesophagus; *pro.t*, Prothorax; *mesa.t*, Mesothorax; *meta.t*, Metathorax; *g*, *g*, Ganglia of Chief Nerve Chain; *u*, Nerves; *hs*, Honey Sac; *p*, Petaloid Stopper of Honey Sac or Stomach-Mouth; *c.s*, Chyle or Gland Plates of Colon; *bt*, Biliary or Malpighian Vessels; *st*, Small Intestine; *l*, Lamelle or Gland Plates of Colon; *li*, Large Intestine. B. Cellular Layer of Stomach—*gc*, Gastric Cells, magnified 200 times. C. Biliary Tube—*bc*, Bile Cells; *t*, Trachea. D. Inner Layer of Gastric Tube—*gt*, Gastric Teeth.

BEES & BEE-KEEPING;

Scientific and Practical.

*A Complete Treatise on the Anatomy, Physiology,
Floral Relations, and Profitable Management
of the Hive Bee.*

BY

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"HONEY AS FOOD;" "THE APPARATUS FOR DIFFERENTIATING THE SEXES IN BEES AND WASPS;" "THE RELATIONS OF INSECTS TO FLOWERING PLANTS;" "FOUL BROOD NOT MICROCOCCUS BUT BACILLUS—THE MEANS OF ITS PROPAGATION, AND THE METHOD OF ITS CURE;" ETC., ETC.

With Numerous Illustrations of the Internal and External Structure of the Bee, and its Application to Plant Fertilisation; Bee Appliances, and Methods of Operation, Diseases, &c., expressly drawn for this work by the Author.

VOL. I.—SCIENTIFIC.

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PREFACE.

IN deference to repeated requests, made by many unknown correspondents, as well as by those who have listened to his Courses of Lectures, the Author has prepared the following pages for publication; and, in presenting them to the attention of the Scientific and Bee-keeping public generally, he also fulfils a promise, given ten years since, in his "Practical Bee-keeping," for the very flattering reception of which he now tenders thanks to his numerous readers.

The unique character of the present work will explain and excuse the delay in its appearance; for the Author has never scrupled to devote time without stint to the solution of any difficulty, and has preferred, in every possible case, to put generally received statements to the test of careful experiment before adopting them as his own. This has led to numerous discoveries, which altogether change the aspect of some parts of the subject; while many old landmarks have had to submit to modifications in their positions, or absolute displacement. The Author acknowledges that he possesses rather the spirit of the progressionist and investigator than that of the antiquarian, and, should he in any case be suspected of having been led

into a too hasty substitution of a new theory for an old, he begs no other indulgence, than that his conclusions should be tested with care at least equal to that by which he has endeavoured to support them. He thus trusts that, truth prevailing, the little corner of the vast field of human inquiry in which he has had the honour to labour may be enriched by facts which may give a new departure, and make Apiculture both more delightful and more profitable, because more intelligent.

It has been thought wise to treat, as far as possible, the Scientific and Practical aspects of the question, notwithstanding the close dependence of the latter upon the former, in two separate volumes, which should be, together, a complete guide in all matters, both touching the Natural History and Management of the Hive Bee. Of these volumes, the first is mainly devoted to the consideration of the anatomy and physiology of the bee itself, the peculiarities of the sexes, and the principles of comb structure, while the fascinating botanical question of the relation of bees to flowering plants has been rather fully treated. The Illustrations here are, in some points, like those in the Author's large Diagrams, published by the British Beekeepers' Association, and which, unfortunately, have been copied by one or two writers with a faithfulness which is flattering, although, with a reticence far more common than commendable, they have abstained from mentioning the source whence their material has been

derived. The second volume deals directly and very fully with Practical and Commercial matters, but always in the scientific spirit, for this separation has been carried so far only as the convenience of the reader seemed to demand—*e.g.*, chemical and chemico-physiological matters touching the nature of honey—its value as a human food; its adulteration, and tests for the same; artificial foods for bees, and their essentials; the characteristics of pure bees' wax, and many other such, beside the highly important, and now extensive, question of Bee Diseases, and their Treatment, the latter being necessarily discussed in the light of the microscopical discoveries, upon which all knowledge of the subject really rests.

Investigators, discoverers, and inventors have been duly credited, and all sources of information stated; the works also, within the knowledge of the Author, which might be useful to the reader desiring to prosecute any special point, have had their titles given in full in footnotes.

While coveting for this effort the encouragement which former ones have received, the Author desires to acknowledge the assistance given by his Publisher, who has aided him in every endeavour to make "Bee-keeping, Scientific and Practical," worthy of support; and to a loving Daughter, who has read his proofs, it is a deep pleasure to express his indebtedness.

AVENUE HOUSE, ACTON, W.,
January, 1886.

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BEES & BEE-KEEPING.

INTRODUCTION.

THE Hive Bee, from the wonders of its social economy calling into play instincts as remarkable as they are inexplicable, has for many ages commanded the interest and the admiration of men; and since it is at least the storer of saccharine substances in a most convenient and delicious form, which, before the general introduction of the sugarcane, supplied in a unique manner a human want, it has been, during many centuries, associated with mankind by a bond of necessity second only, perhaps, to that which linked our forefathers to the cow, the sheep, and the horse. Although *we* are less dependent upon its untiring industry, its sweet product and tuneful hum are as grateful as ever; while scientific investigation has shown to us that the little labourer is a prodigy of wonders, of which those of a hundred years since had not a suspicion; and, as revelation after revelation opens up before

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us, our interest intensifies and our minds delight themselves, as they ever must when properly engaged in studying the works of creation. Very much, however, that has passed current as accurate and established, has not borne the test of recent scrutiny; and it will be in part the object of the following pages to expose mistake, and supply its place, where practicable, by truth. The departure of fable will, however, never leave a void, since human imaginings are always unequal to Nature's resources; so that here, as everywhere, "fact is stranger than fiction." In treating far more completely than has previously been attempted the anatomy and physiology of the insect which has made for itself by far the largest place in literature—the sluggard-rebuking ant not even excepted—the writer will be found frequently to differ from the conclusions of others; but never has he ventured so to do without the most careful and scrupulous investigation, aided by the most refined microscopical appliances. Again and again he will, in obedience to truth, be forced to show that many time-honoured statements have originated, not in painstaking study, but in crude and daring guessing, or in a carelessness of observation almost equally blameworthy. On the other hand, however, the pleasure will often fall to him of pointing to the discoveries of such men as Siebold, Leydig, and Schiemenz, amongst naturalists, as well as to the achievements of the older apicultural worthies, and the beneficial results of the energy and perseverance of many still amongst us, whose names are familiar as household words.

A very large part of our matter will be in all respects absolutely new, being the issue of researches, dissections, and experiments, which have, in connection with the practical work of the apiary, occupied delightfully no inconsiderable fraction of many years of a busy life. The anatomical, physiological, and botanical illustrations, which, to a work like the present, are as important as the text, have been in every case, save one or two, drawn by the writer on the wood, direct from his microscopical preparations, or the objects *in situ*, as the case may be; and it is hoped that they may form in themselves a contribution to the general knowledge of the subject, which may advance apiculture a stage in the direction of a true science. The accuracy of the drawing may, it is believed, be relied upon; but, notwithstanding earnest effort on the part of draughtsman and engraver, producing results which it is felt will not suffer by comparison, it must still be confessed that the subtleties of Nature are in advance of the refinements of Art, and that it has not been possible in every case to secure full details. The drawings are all to scale, which has usually been given with the description. This fact will make the illustrations of appliances peculiarly serviceable, since all measurements can be readily ascertained, even where they have not been stated.

Our title is a compound one, and our treatment shall be complex. Practical bee-keeping is the outcome, and not the parent, of a scientific knowledge of bees and their relations to the world about them. Practical men have not made scientific apiculture;

but scientific men have given to practical ones not only true methods, but reasons for their truth, and so we logically place our scientific matter first, and then look at our systems of operation in the light thus gained. "Practice makes perfect," is but a half truth. Practice, without intelligent insight, only stereotypes; but practice, hand-in-hand with accurate knowledge and observation, works out perfection. It is our hope, then, not only to delight the student of Nature by introducing to him beauties of structure, wonders of adaptation, and minute refinements, to which our conception is almost unequal, but to aid to the full the bee-keeper, who can be charmed through the pocket as well as the imagination. Apiculture may be, and often is, profitable, ah, very profitable, in the hands of those who would not claim any scientific acquaintance with it; but such from the teachings of others always adopt scientific methods. While the course of events is not unusual, deputed knowledge may be enough; but management of the highest type—*i.e.*, the most remunerative kind, can only be arrived at by something better than rule of thumb. In critical matters, the best informed are the most trustworthy guides, and knowledge, which appears to have little to do with the practical side of the question, not infrequently turns out to be the solver of an otherwise unsolvable mystery, and the source of the best, because truly scientific, method of procedure.

The ever-increasing zest attaching to apiculture, the multiplication of bee-keepers, the competition of dealers, and the ingenuity of inventors, has augmented

appliances in a surprising and somewhat bewildering fashion. The endeavour to increase profits, and make a market for honey, by saving the labour of the bees and their owners, and by tempting the purchasers of the results of the efforts of both, has put before us a miscellany of articles, which our ancestors would have regarded as fearfully and wonderfully made, but which they never could have supposed to have any relation to bee-keeping. It will be our desire to do full justice to these, both by explanation and illustration; but, at the same time, by carefully elucidating principles, to so guide the bee-keeper, that he may be well able to so select both hives and appliances, that all his requirements will be met by the smallest possible collection of bee paraphernalia.

The increased attention which apiculture has received during recent years, not only in our own country, but on the Continents of Europe and America, is due to a variety of causes. With us, some of these are personal; and first in the roll of honour amongst those who have with philanthropic ends attracted attention to apiculture, must stand the name of the Rev. Herbert R. Peel, whose very recent death all must deplore, especially such as knew him so intimately as the author. But the causes mainly are of a more permanent kind than can be those that are associated with the proverbial uncertainty of human life; *e.g.*, honey is a wholesome delicacy, which sugar has supplanted, but not replaced; so that this product of the apiary is winning for itself anew a position in our diet tables, and we are also beginning to re-

discover virtues in honey which had been well-nigh forgotten. Old systems were clumsy and uncertain, and yielded, at the best, but poor results. Our modern plans give us complete mastery of our bees, and enable us to obtain from five to ten times the weight of honey from a single stock that the old hands ever secured. Their honey in the comb was generally stained, always irregular, and never to be touched without leaving a sticky trail; ours, if we know the art, is faultless in colour, flat as marble slabs, and would not sully the daintiest glove. Theirs, when "drained," or "squeezed," was often dirty and contaminated by brood juices; ours, thrown out by the extractor, is bright and clear, and of perfect purity. It is no wonder, then, that purchasers increase and apiculture is stimulated. There is a charm, too, in modern bee-keeping, which never existed when the hive was a sealed book and the bee supposed to possess two points of interest only, and those at its extremities — its tongue and its sting — which had nothing particular between them—to use the words of a humorous writer—save "skin and squash."

The amateur, the naturalist, and the trader, alike find more to delight and attract than was formerly possible, while the general public are beginning to be more alive to the advantages which honey possesses as a food. Apiculture, then, has a *raison d'être* which assures its permanence, a pleasing thought to those who know how much bees have to do with securing for us a fruit crop, and fertilising many of the plants cultivated by the farmer.

CHAPTER I.

WILD AND HIVE BEES.

*The Position of the Hive Bee in the Animal World—
System of Classification—Family Apidæ—Megachile
centuncularis—Humble Bees.*

NATURE, with a prodigality which bespeaks infinite resources, has spread before the bewildered naturalist between a quarter and half a million species of creatures inhabiting land and sea. To marshal into system this vast host, certain marked characteristics have at first been laid hold of, so that all might be collected into a few divisions. The classification of Huxley, which I shall adopt, thus brings the whole animal world under seven heads, denominated sub-kingdoms, because life, in the widest sense, has been arranged under kingdoms—the animal and vegetable. The second sub-kingdom, *Annulosa*, embraces all those whose bodies are definitely arranged in rings, including such unlike creatures as house flies and leeches, so that this sub-kingdom is naturally split into two parts—*Arthropoda* and *Anarthropoda*,* meaning those that

* ἄρθρον, a joint, and πούς, a foot, with the Greek privative ἀν.

have and those that have not jointed feet. The fly and leech thus part company, while, of course, our bee takes its place in the first division; but even here we have wide diversities between creatures that cannot claim kinship, such as butterflies, spiders, and lobsters, the whole of which conform to the distinctions up to this point established. The *Arthropoda* are, therefore, separated into four classes, the first of which is *Insecta*—insects having all certain well-marked peculiarities that will appear in the sequel; but it is sufficiently exact for our present purpose to now briefly state that the Hive Bee is an insect because its frame is divided by deep constrictions into three parts. First, the head; second, the thorax or chest, to which are articulated or jointed the legs and wings; and third, the abdomen.

Much as we have now narrowed our limits, this definition still embraces a vast multitude of creatures—comprehending moths, beetles, and flies—which would appear to have little affinity with bees, and so, for purposes of classification, other distinctions are introduced, insects being separated into thirteen orders, of which the *Hymenoptera*, or those carrying four gauzy wings, includes not only bees, but also wasps, ants, and some others. The *Hymenoptera* being again parcelled out into families, distinct places are found for the latter insects, while our favourites appear amongst the *Apidae*, or long-tongued bees, which, in company with the *Andrenidae*, or short-tongued bees, comprise about 2000 distinct species, of which 212 are acknowledged natives of Britain, and these, although differing greatly amongst themselves in size,

colouring, and habits, possess strong resemblances in structure, suiting them all for honey and pollen gatherers.

These pre-eminently useful little labourers forming the families of the *Apidæ* and *Andrenidæ*, as we have already said, and of the merits of whose work we cannot speak until we come to discuss their relations to flowering plants, are far too much strangers to bee-keepers. The big Humble is everywhere recognised, and frequently its nest is not unknown; but the smaller solitary bees are not certainly acquaintances of the ordinary bee-keeper, notwithstanding his deep interest in their near relative. It will be well here, therefore, to introduce one or two for future identification, and these will also serve for the purposes of illustration and comparison.

Standing by a rose bush, we note the descent of an insect, somewhat less than a honey bee, black-backed, with reddish hairs on the thorax, and light down upon its head and three first abdominal segments. It poises itself a moment above a selected leaf, and, settling, immediately commences cutting with its mandibles, which act like a pair of scissors. Quickly, a most regularly formed piece is detached, which does not fall, heavy though it appears in comparison with the size of the insect, for legs and jaws continue to hold it, and away she flies towards her nest.

I examined one of the latter recently, which had been dug in the side of a quiet lane. The *Megachile centuncularis*, for such is the name of this little

bee, had excavated a hole, at first perpendicularly, and then horizontally, about 5 in. in length. The work of lining the tube with leaf had commenced by cutting from some rose bush a circular piece, curling this, and carrying it to the bottom of the tube, and spreading it, without a wrinkle, into a saucer form, to cover the end. Now the jaw scissors had been set to snip out from the leaf-side spindle-shaped pieces, which, brought one by one to the nest, are applied to the wall at the bottom, and made to overlap so cleverly that the earth is entirely covered, while the serrations of one piece, worked alternately in front of and behind the cut edge of the next, hold all in exact position without any cementing. We have now the representative of one cell of ordinary honeycomb, and the analogy continues in that the *Megachile* proceeds to her feeding-ground amongst the thistles, from which she collects pollen by hair brushes on her hind legs, whence it is conveyed for temporary storing to feather-like appendages on the under side of the abdomen; honey is gathered by her tongue; and thus furnished, she proceeds homewards to practise the art of pudding making, for the two materials are kneaded together, and increased in volume by repeated visits to the thistles, until a stock of food, in all respects resembling that used in the bee-hive, and sufficient for one of her progeny, fills her leaf-lining nearly to the top. Her first egg is now deposited, from which, in due course, will issue the humble grub, which, through Nature's far-sightedness, with all its humility, is still born to a competency. The cell

needs closing, while its cover is made to form the floor of the next. Once more, then, the rose bush must contribute perfect circles, for the cutting of which no compasses are required. To the number of four or five these are laid, one upon the other, and pressed smoothly into position; the wall-lining is added, a second pudding and egg provided, and the processes repeated until five or six chambers are complete, and the work of the little labourer brought to a close. And now, strangely, the last deposited egg is the first in the order of time to hatch. The grub emerging does as a grub so placed must: it consumes its pudding, and begins to occupy the space its food previously filled. The mother had accurately judged, if she could judge at all, the needs of her son, for this grub is a male. The pudding is gone, and he is satisfied, and now begins to spin a cocoon, and then passes into the chrysalis condition, and presently we have the perfect male *Megachile* biting and pushing up the leafy cover, and escaping into the sunlight of a new life. By his emergence, he has opened up the way for his brother, and he in turn will remove all impediment to the escape of the sisters below. Thus the community of young *Megachile* is provided. The old ones are gone, but the race lives. Their marriage bells are rung while the autumn sun is shining; the males die, the females seek screening from the chilly blasts which must blow before their work of nest building can commence, and so the circle is completed.

How unlike, and yet how very like, all this to the

Hive Bee. As we become acquainted with the latter, we shall see that the mother *Megachile* is queen and worker combined; the male, the short-lived drone. The cell, its sealing, the food, the egg, the tongue, the hair brushes, the abdomen of the two insects, counterparts of one another in each case. All Nature is one, and the student of the Hive Bee is unwise, and self-deprived of the knowledge of much that is marvellous and delightful, if he altogether neglect all members of the family *Apidæ* save its head and most perfect representative.



FIG. 1.—THE HUMBLE BEE (*BOMBUS*).

The Humble Bees, or *Bombi* (Fig. 1), come nearest to our Hive Bees in that they are semi-social, living in companies during the summer, the queen passing the winter in solitude. The big downy and noisy insect that visits our gardens in the spring is a mother *Bombus*, that spent her honeymoon the previous autumn, in like fashion with the *Megachile*, and subsequently sought out for herself some narrow retreat in which to hibernate; but, so soon as the shallows yield their pollen, she is abroad and preparing for the progeny by which she is presently to be surrounded. Different species have different habits, but

in every case the hibernated mother commences a nest alone; e.g., the *Bombus muscorum*, known by its light and dark brown hairs, establishes itself not infrequently in the middle of fields, taking care that the spot selected is in the neighbourhood of abundance of flowering plants. A vaulted roof is formed of cleverly entangled pieces of moss, plastered beneath by a layer of greyish wax, and so rains, which would pass the moss, are effectually kept out. Pollen and honey are collected in pellets, eggs laid, and so, in due course, workers produced; for, as her children gather about her, the mother leaves to them the duties of nest extension, cell construction, and food collection, and, confining herself to ovipositing, becomes a stay-at-home, and a very close representative of the so-called queen of the bee-hive.

Later in the season, instead of workers, which are much smaller than the queen, a *Bombus*, a size between the two, begins to make its appearance in the nest; this is the male, and now, soon, creatures as large as the original mother are added to the colony. These, the true females, mate as we have hinted, and alone survive the rigour of winter to be the instruments for continuing the race. To those conversant with Hive Bees, the closeness of the analogies between the two insects last mentioned, will suggest themselves; but they will become evident to all as we study the next chapter. Amidst the analogies, however, there are differences, and so the family of British *Apidæ* are marked off into nineteen genera, the typical genus being *Apis*, in which the Hive Bee finds its place. In this genus, there is but one British species, *mellifica*,

although some others are cultivated as imported bees, and notably *Apis ligustica*, or the Ligurian bee; so that the whole classification of the subject of our study would take the form now given:

Kingdom	Animal.
Sub-Kingdom	Annulosa.
Division	Arthropoda.
Class	Insecta.
Order	Hymenoptera.
Family	Apidæ.
Genus	Apis.
Species	Mellifica.



CHAPTER II.

ECONOMY OF HIVE BEE.

Gathering Bees—Comb—Pollen and Honey—Eggs, Larvæ, and Pupæ—Foragers and Nurses—Skin and Bowel Moulting and Cocoon Spinning—Drones and Queens—Swarming and Comb Building.

IN order that we may possess an intelligent understanding of the need and suitability of the various complex parts and organs proper to Hive Bees, and which we are about to consider in detail, it will be necessary for us to pass in review a general outline of the economy of the hive, noting at present only the salient points. We will imagine that our study is undertaken on a fine summer day, and that the hive we have at command is in a normal, healthy, and prosperous condition, and such an one also as to afford us every facility for examination. As we stand before its entrance, bees in quick succession make their appearance at the hive door, and in such haste as seems to indicate that they are impressed with the importance of their mission, for they are no sooner well visible than they are away in some definite direction; but others are returning, and these,

settling, in a great number of instances, show us that they are carrying on their hind legs relatively large masses of coloured material, which is most generally some shade of yellow or orange, although crimson, green, and even black, may be seen. This material, considered by the ancients to be wax, and called by Réaumur himself *la cire brute* (crude wax), we shall, in due course, learn to be pollen, which has been gathered from the anthers, or male organs of blooms, by a most beautiful set of apparatus, to be hereafter examined. Opening our hive



FIG. 2.—BAR FRAME OF HIVE.

by the removal of the top cover, so as to expose our stock (as we commonly denominate a colony of bees in an established condition), and in order that we may learn the behaviour of those that are returning from their aerial voyages, we find it filled with combs, each one of which is a tolerably flat slab, about 1 in. in thickness, fixed in, and mainly hanging from, the upper side or top bar of such a frame as is shown at Fig. 2. These frames are so placed and arranged that each may be easily lifted out with its attached comb, which has, in turn, its face $\frac{1}{2}$ in. distant from

its fellow on either side. These interspaces are well filled by bees, but very few of which disturb themselves on our account; nor need we be disturbed on theirs if, with precaution, we lift out one of these filled frames for inspection, the bees retaining their

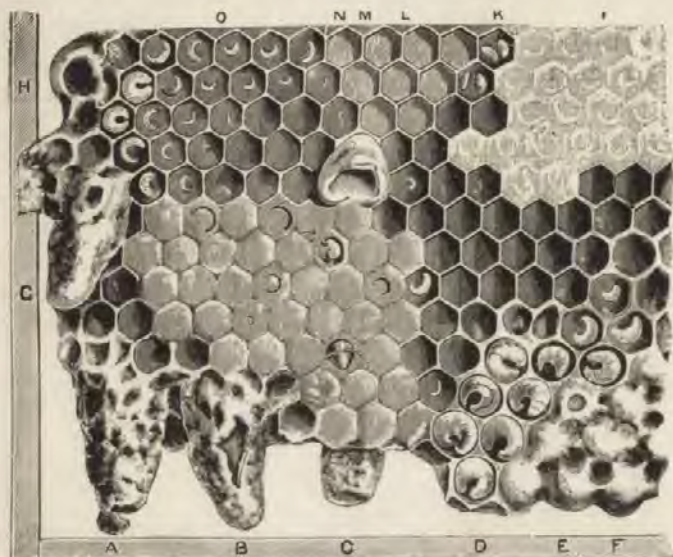


FIG. 3.—HONEYCOMB (Natural Size).

- A, Queen Cell, from which Queen has hatched, showing Lid; B, Queen Cell torn open; C, Queen Cell cut down; D, Drone Grub; E, Drone Cell, partly sealed; F, Drone Cells, sealed; G, Worker Cells, sealed; H, Old Queen Cell; I, Sealed Honey; K, Fresh Pollen Masses; L, Cells nearly filled by Pollen; M, Aborted Queen Cell on Face of Comb; N, Bee biting its way out of Cell; O, Eggs and Larvæ in various conditions.

position, and in large part continuing their work as though nothing particular had happened.

As we now cast our eyes over the comb, delicately and perfectly modelled in wax, we discover that



it is made up of a number of chambers (technically cells), nearly all of which are exactly hexagonal in cross section, and most of which are precisely one-fifth of an inch between the parallel sides. Some of these (L, Fig. 3) are nearly filled by an opaque, dough-like looking body, which we recognise at once, both by colour and consistency, as being that very pollen, packed away, which we saw being carried into the hive on the hind legs of the returning bees. One of the latter, still loaded, marches before us, occasionally sharply agitating her body (for these untiring workers are ladies); and, as we look, she curls herself over a cell, and, by a process singularly beautiful, which we are not yet in a position to understand, she thrusts off one of these lumps into it, and then, by a second twist, the other, either immediately leaving them, as at K, Fig. 3, or else butting them down with her head into a pancake for future use. But her cargo is as yet only half discharged; and now, seeking another cell, either empty or containing some honey, she inserts her tongue, and returns from an interior cavity of her body, called the honey sac (*h s*, Plate I.), the sweet fluid she has collected from the nectaries of flowers. As duty and pleasure are synonyms with a bee, she at once hies away, in order that, ere long, she may yet again add to the riches of the community for which she lives to labour. And, we ask, why this anxiety to carry home both pollen and honey?—some of the latter standing before us in considerable quantity, beautifully covered by air-tight, either white or yellowish, caps of wax, seen in Fig. 3, at I. A reply is soon

furnished, as we notice, at the bottoms of numbers of the cells, whitish tiny legless grubs (O, Fig. 3), evidently incapable of seeking their own food in any way. This is brought to them by the younger bees of the stock, which do not normally fly abroad, but which make the helpless larvæ (grubs) the especial objects of their care, elaborating for them the two kinds of "pap," which form their sole nourishment, by a process respecting which great errors have been propagated. We shall have much to say about it presently. The materials required for the somewhat circuitous elaboration of the given food are honey, pollen, and water, which last, if need be, is brought home in quantity, the former two being placed in the store cells, as we now understand, by the foragers, the name commonly given to the flying bees, while the feeding bees are very appropriately called nurses, although there is no actual distinction between them, as some former writers thought. Growing older, the nurses turn to foraging, but they do this in consequence of a glandular change coming on with age, which makes nurse work unsuitable; but more of this hereafter. This pap may be seen, in appearance like arrowroot made with water, surrounding the bodies of the grubs (see FL, Fig. 4). They partially float in it, and, besides absorbing it by the mouth, are commonly supposed to take it in by that part of the skin which is submerged; but it is not correct, as stated by Cook, for reasons presently given, to say that the food is "*all* capable of nourishment, and thus all assimilated."

These model nurses are ever perambulating the

combs, and, in the darkness of the hive, so examine the contents of every cell, by exploring it with their thread-like antennæ—which are most sensitive organs, placed between the eyes, and well seen in many subsequent illustrations, especially Plate II.—that no grub escapes due attention, and food follows close upon appetite, although, in a strong colony, often as many as 12,000 larvæ will need pretty frequent visitation. The larva, or grub, grows apace, but not without experiencing a difficulty to which the human family is, in some sort, subject in the period of youth. Its coat is inelastic, and does not grow with the wearer, so that it soon, fitting badly, has to be thrown off; but, happily, in the case of the larva, a new and larger one has already been formed beneath it, and the discarded garment, more delicate than gossamer, is pushed to the bottom of the cell. It would be singular, were it not for the abounding errors of bee literature, that Réaumur and Huber have asserted (followed by many others with a uniformity which is not the outcome of investigation) that the bee larva does not change its skin, but only grows larger. A little patient looking would have found the old and ruptured pellicles, and so pretty conclusively have settled the question. In like manner to the first, moult succeeds moult, to the probable number of six, when, after about four days' feeding, the well-nourished creature, loaded with fat, lies at the lower part of the cell curled up, as one is seen to do near H, Fig. 3. At this time, its weight is scarcely less than double that of the bee into which its natural transformations will

by-and-by convert it. No more food is supplied, and the period for cocoon spinning approaches. The silken threads forming this (*co*, Fig. 4) are produced by a fluid yielded by a gland (Fig. 15), which re-appears in the adult bee. This fluid escapes by an aperture in the lip, and very quickly hardens into what may be described as bee silk. Before the cocoon can be built, a cover, technically called sealing, is put over the larva by its nurses, that now bid it farewell. These covers are seen in numbers at G, Fig. 3; they are pervious to the air, are made of pollen and wax, and are more convex and regular in form than those sealing in the honey (I, Fig. 3); and, behind them, a series of most wonderful and bewildering changes occur; but, ere they can commence, a preliminary step is necessary, which seems to have altogether escaped the attention of both scientific and practical writers. The food given to the larva, especially during the latter part of the growing period, contains much pollen, the cases of the grains of which consist of a substance called cellulose, which is perfectly incapable of digestion. These cases, with other refuse matters, collect in quantity within the bowel, which becomes distended, since it has no opening (*mb*, Fig. 13). The imprisoned larva, having little more than enough room for turning, must be freed of these objectionable residua; but Nature is equal to the difficulty, accomplishing all in a manner commanding our admiration—and here we can but outline, reserving a fuller explanation till we consider the structure of comb. In a word, the larva turns its head upon its stomach, and pushes

the former towards the base of the cell until its position is reversed, the tail being outwards, and, thus placed, it laps up all residue of food, especially from its old clothes previously referred to, until they are dried, and practically occupy no space. It now throws up its stomach and bowel, with all their contents, and without detaching them from its outer skin, which is moulted as before, but, in this instance, to be pressed against the cell, so as to form for it an interior lining. The dejectamenta of the bowel in

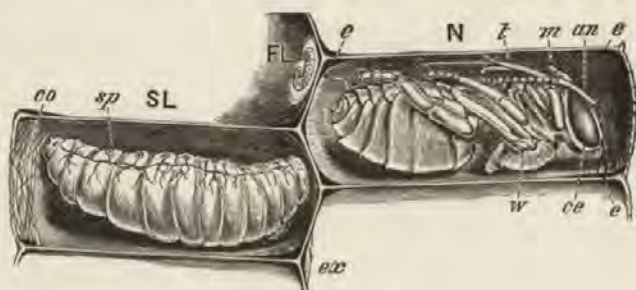


FIG. 4.—LARVA AND CHRYSALIS (Magnified Four Times).

SL, Spinning Larva ; N, Nymph or Chrysalis ; FL, Feeding Larva ; co, Cocoon ; sp, Spiracles ; t, Tongue ; m, Mandible ; an, Antenna ; w, Wing ; ce, Compound Eye ; e, Excrement ; ex, Exuvium.

this way lie between the cast skin and cell wall (as seen at *e*, Fig. 4), and so the larva remains absolutely unsoiled. It now turns its head and resumes its old position, joining its cocoon to the edges of its last cast skin, so that its habitation is relined, it is cleansed, and air can still pass to it through the imperceptible openings left by the bees in the sealing. This point is of radical importance, since breathing is carried on pretty rapidly during the

latter part of its subsequent transformations, the absorbed oxygen permitting then of a production of heat, and causing also considerable diminution in weight. Having thus put in order the cell containing it, the larva remains for some little time in a condition of quiescence, and now, under the new name of chrysalis, pupa, or nymph (N, Fig. 4), enters upon the sequence of transformations, all slowly and quietly effected, which end in converting it into a new creature. Constrictions occur, and rings or segments vanish, until the body becomes head, thorax, and abdomen. As it lies upon its back, prominences begin to show themselves, which become more and more pronounced, until, at last, they sufficiently assume the form of legs to be recognised; these are six in number and are much more than organs of locomotion, as they bear, curiously disposed upon their many joints, a whole set of tools singularly varied in modelling and application; a tongue, too (*t*, Fig. 4), replete with wonders, and lying stretched along above the body, begins to be seen; and then, drawn round from the back of the thorax, like a girl's cloak which she has allowed to slip from her shoulders, are gauzy but many-folded extensions, which hereafter become the beautiful instruments of flight (*w*, Fig. 4). But these external changes, marked though they be, are transcended by the wonder of the progressing interior modifications and developments. The nerve system is recast and enlarged, the digestive apparatus changed, an entirely new set of muscles and tendons brought into existence; glandular structures make their appearance, breathing tubes or trachea in untold number come into

being, and, in short, an organisation is built up which has baffled, and is still in great part baffling, our highest powers of research. That which was the blind grub, living in darkness, is soon to be the active bee, rejoicing in the sunbeam, attracted both by the perfume and the colour of flowers, and so organs of sense are being prepared for it, the structure of which we cannot yet stay to consider; the antennæ are developing, and, at the sides of the head, dark brown spots are indicating the position of the future compound eyes. In something more than twelve days from the time of sealing, the transformations are complete, and a pellicle, delicate as cobweb, is rolled from every part of the frame, and pushed downwards to the base of the cell (*ex*, Fig. 4), where we soon may be at liberty to find it, for now a creature, lacking in nothing that its subsequent duties will require, bites at the door of its prison-house, into which it soon carves a long, curved slit, as seen in three or four cases (Fig. 3); and then, by a push, it makes way for its emergence, the head is advanced as at N₁, and a pale but perfect bee walks into view. Its down, like that of the recently-hatched chick, adheres, but soon it will dry and preen itself, and in twenty-four hours we shall have our nurse already entering upon her duties to spend and be spent, in order that she render to others those very attentions she has herself received.

But we ask, Whence the grubs whose history we have so far examined? and now, in searching, we discover, on one of the combs, an insect—commonly but very erroneously called the queen (Fig. 5. *b*), for

she in no sense governs—longer in body than the worker (Fig. 5, *a*), and really differently formed in every part, and possessing most active and curious egg organs, called ovaries, which are capable of yielding a prodigious quantity of eggs. As we watch this queen slowly progressing, with a number of workers about her, touching her continually with their antennæ, and backing out of the way so as not to impede her movements, she dips her head very deeply into a cell, and, having satisfied herself that it is empty, she advances a step, holds on to the edges of the comb, principally by her second and



FIG. 5.—HIVE BEE (*Apis mellifica*), Natural Size.

a, Worker; *b*, Queen; *c*, Drone.

third pairs of legs, and, curling her abdomen, inserts it into the examined cell, until it is almost entirely hidden. A moment of apparent stillness; she recommences her walk, her abdomen straightens as it rises from its hiding place, and we immediately see that she has left behind a tiny long and narrow pearly-white egg, fixed by one end to the cell bottom. The queen quickly repeats the operation, the neighbouring nurses being always ready to offer food. Their attentions are, as we can easily see, needful, but many writers have given the echo to a medieval fancy by stating that she is ever surrounded by a

D

circle of dutiful subjects, reverently watching her movements, and liable to instant banishment upon any neglect of duty; these it was once the fashion to compare to the twelve Apostles, and, to make the ridiculous suggestion complete, their number was said to be invariably twelve. If all this were true, beginners in bee-keeping would not find the difficulty in discovering a queen which they sometimes experience. But to resume. The egg contains a germ, which, kept warm by the native heat of the colony, and fed by abundance of yolk, will develop into a grub, which, in some instances, frees itself from the egg case by struggling into the first quantities of food put into its cell by the nurse bees, the very condition in which we just now made its acquaintance.

We have already learnt that the worker bees are female, but they are sexually aborted, and normally incapable of laying eggs. The queen, or mother, on the contrary, is fully developed, and her capacity for egg-production is immense, a good queen being able to furnish to the cells an average of two eggs per minute for weeks in succession. A new question now arises, Whence the queen? and we are brought face to face with a difficulty which even yet we may not have fully surmounted, although, in a later chapter, I hope to give a relatively more satisfactory answer than has yet been attempted. The queen, in short, is produced from an egg in all respects identical with the eggs which furnish the workers. The difference is brought about by a change of treatment to the grub on the part of the nurses. When a queen is to be

produced, a cell of large size and extraordinary form is constructed (A and B, Fig. 3), and, by special feeding of its occupant, instead of a worker, a queen is evolved. She, being a female, needs a mate, and such is found in the drone (*c*, Fig. 5), or male, which has a very complicated structure, that must be duly considered under its proper head. The drones are produced in larger cells than the workers, so that their more rotund forms may be accommodated. Their cells are a quarter of an inch in diameter, and are seen over D, E, F, Fig. 3, and may always be recognised when they contain sealed brood (the name for inclosed larvæ) by the very convex forms of their cappings. The eggs to provide these males are also laid by the queen, and are, whilst in her ovaries, absolutely like those that furnish both queens and workers. When, however, the latter are to be evolved, by a somewhat complicated act occurring in the body of the queen just before the egg is deposited, fertilisation takes place by the addition of material originally received from the drone. When drones are to be produced, this addition is withheld and the eggs are laid unimpregnated—*i.e.*, drones have a mother, but no father, a question, the examination of which, with the anatomy of the parts involved, will be fully explained and illustrated as we proceed with our task.

The tremendous fecundity of the queen, in favourable conditions, so multiplies the number of bees, that a division of the community becomes necessary, beside which, these wondrous little animals have an essential and deeply-rooted colonising instinct, upon obedience to which they often insist with singular

pertinacity. Since a queen is essential to the existence of a stock, as she alone can produce eggs, a new queen, under these circumstances, must be produced, and so bees form queen cells, and previously bring forward drones. The old mother departs with the superabundance of the population. A queen, matured soon after her migration, occupies her place after having consorted with a drone, so as to secure the honours of maternity.

Such, in few words, is swarming. The swarm needs powers we have not yet considered. Its new house requires furnishing, and, to compass this, first wax is secreted from the bodies of the workers, and then, by an architecture which is rarely, if at all, exceeded in beauty and adaptation even in the insect world, combs are built of dainty purity and almost mathematical exactitude ("almost" is here said advisedly), and so a place is given, as the cells multiply, for the eggs of the accompanying mother and for the incoming riches brought home by the never weary foragers; and if weather be favourable, or, what is even better at this particular point, the bee-keeper intelligent and attentive, our swarm quickly passes into a stock, and will yield us all the interesting points which have as yet occupied our attention. It is now clear that the mysteries of the economy of the hive, the varied instincts brought into exercise, and the wondrously complicated and delicately beautiful organisations of the little labourers making their purposeful lives a possibility, will give much occupation during succeeding chapters.

CHAPTER III.

GENERAL STRUCTURE.

External Skeleton—Chitine—Hairs and their Uses—Breathing Apparatus: Spiracles and Tracheæ: Air Sacs—Circulating System—Dorsal Vessel—Pericardial Cavity—Blood of Bee—Peritracheal Circulation—Muscular Fibres, and Methods of Movement—Muscles of the Jaw—The Minute in Nature.

OUR bee is now before us, for we have witnessed the laying of the egg, the growth of the larva, the development of the chrysalis, and the initial life of the imago, and, as we pursue our study of the intricacies now awaiting us, we shall find it more convenient to treat under separate heads the nerve system, the digestive apparatus and glandular systems, the external organs of sense and locomotion, with those special parts that distinguish queens, workers, and drones; but, at the same time, it will do us good service first so to examine the general structure that we shall have a grasp, as a whole, of the wondrous mechanism we desire to understand. Let us begin with the external framework, premising that bees, in common with all insects, have formed on every

part of their bodies, by a layer of secreting cells, called the hypodermis, an external skeleton, composed of a remarkable substance, to which the name Chitine has been given. Chitine is capable of being moulded into almost every conceivable shape and appearance. It forms the hard back of the repulsive cockroach, the beautiful scale-like feathers of the gaudy butterfly, the delicate membrane which supports the lace-wing in mid air, the transparent cornea covering the eyes of all insects, the almost impalpable films cast by the moulting larvæ, and the black and yellow rings of our native and imported bees, besides internal braces, tendons, membranes, and ducts innumerable. The external skeleton, hard for the most part, and varied in thickness in beautiful adaptation to the strain to which it may be exposed, gives persistency of form to the little wearer; but it needs, wherever movement is necessary, to have delicate extensions joining the edges of its unyielding plates. This we may understand by examining the legs of a lobster or crab, furnished, like those of the bee, with a shelly case, but so large that no magnifying-glass is required. Here we see that the thick coat is reduced to a thin and easily creased membrane, where, by flexion, one part is made to pass over the other. Likewise, in the antennæ of the bee (*a*, Plate II.), the insertion into the head, by a sort of ball and socket joint, covered by chitine so thin and transparent that nerves may be seen through it, admits of the varied movements proper to this instrument of inter-communication; for it is hardly too much to say that, by means of the antennæ, the intelligent little creatures talk.

Again, almost every part of the body is covered by hairs, the form, structure, direction, and position of which, to the very smallest, have a meaning. These are also formed of chitine, and framed for varied uses. The external skeleton, mainly protective in character, is *not* sensitive, and so a large proportion of these appendages are curiously formed (as at C, D, E, and H, Fig. 24), with a bulb at the base, to accommodate a nerve end, by the presence of which they become, in each individual instance, truly organs of touch. Beside this, they act as clothing, the thoracic and abdominal pubescence, or fluff, aiding in retaining heat, and give protection as the stiff, straight hairs of the eyes (Plate II.), whilst some act as brushes for cleaning (*eb*, C, Plate V.); others are thin and webbed, for holding pollen grains (as I, Fig. 24); whilst, by varied modifications, others again act as graspers, sieves, piercers, or mechanical stops to limit excessive movement. Possibly, the hairs are not exclusively utilitarian, since those on the dorsal part of the abdominal rings would appear to be intended mainly as a decoration.

Whilst carefully scrutinising a worker and a drone by the aid of a hand magnifier, or watchmaker's eyeglass—and every intelligent bee-keeper should at least possess some such apparatus—we note that the abdomen of the worker, like that of the queen, is surrounded by six belts of chitine, each being made of two plates—one, larger, on the back (the dorsal plate), overlapping the second, smaller, or ventral plate, which is applied to the lower side of the body. This arrangement is well shown in the chrysalis

(N, Fig. 4), or in the cross section of imago (Fig. 8). The drone is similarly formed, but has seven belts or rings. These, in both cases, if the specimens are living, are continually slipping in and out upon each other like the joints of a telescope, their attach-



FIG. 6.—AIR SAC AND TRACHEE (Magnified Fifty Times).

a, Air Sac, showing Plaiting; *b*, Spiral Threads of Trachea; *c*, Interior, showing threads; *d*, Single Thread from Small Trachea; *e*, Fine Trachee.

ments being made by delicate membranes, which admit of free movement (abdomen, Plate I.). As these slide backwards and forwards, we catch sight of depressions that are hidden from view when the abdomen is fully drawn in, one occurring near each

end of each dorsal plate save the first. Microscopic examination reveals that we have here openings, denominated spiracles (*sp*, Fig. 8), with strange complications, leading into internal tubes, called tracheæ (Fig. 6), forming the breathing apparatus, and which divide and sub-divide, after the manner of a fibrous root in the soil, until they are found in countless number in every part.

All animals require oxygen. In those above the *Annulosa* (page 7), the blood is carried either into lungs or gills by means of vessels, when it appropriates oxygen, which, by the circulation, it distributes. In insects, with a local exception noticed later in the chapter, there is no system of blood vessels, so oxygen, as a part of the air, is taken direct from the before-mentioned spiracles, through the tracheæ, into all muscles, glands, and organs of the body, not even excepting the wings. As the abdomen is extended and contracted, as is constantly done by the bee, air is drawn into, and then expelled from, these apertures in the sides, precisely as in our own breathing from the mouth. Should an unlucky fly, through not sufficiently controlling his passions and appetites, tumble into the milk, and be saved from a tragical fate by being lifted on to the table-cover, he immediately commences energetically grooming his body with his legs, not because he is especially anxious about his personal appearance, but because here the milk is closing his spiracles, and actually choking him.

The tracheæ consist of an external and internal membrane, between which run spiral threads, highly elastic in character, that prevent the closing of the

E

tube by any bending of the body of the insect, just as the spiral wire within indiarubber gas-piping secures a constant flow of gas, in spite of any twisting of the pipe itself. The embryology of insects has shown that the tracheæ are developed by invagination (a turning inwards) of the outside skin (precisely as the bowel is formed in the larva, see Fig. 13), and that, at the time of moulting, the tubes in the neighbourhood of the spiracles are cast off. That this is true in the bee is easily proved by those having a microscope of even



FIG. 7.—PART OF EXUVIUM OF BEE LARVA (Magnified 100 times).
sp, Spiracle; *tr.l.*, Tracheal Lining.

moderate capability. Lifting from a cell a half-grown larva, a little transparent mass will be observed upon the centre of the cell base, which mass to some extent filled the cavity formed beneath the body as the grub lay head and tail together. This is found to contain one or more cast skins, which carry with them the covers of the spiracles. The investing membrane (Fig. 7) of the contiguous tubes is withdrawn, while the tiny hairs and scales of the body also lose a layer, as we see by the illustration. It is difficult to understand how the extremely thin lining of the tracheæ is

removed, but the fact is evident. From the invagination aforesaid, it follows that the layer which is outside in the skeleton is the inner, or lining one, in the tracheæ, while the hypodermis, which originates the chitinous coat (as has already been stated), and lies, of course, beneath it, has its representative outside the breathing tubes. The spiral thread is produced by the lining membrane, or internal cuticle, forming a chitinous thickening, in a spiral line, which is never continuous for more than four or five turns. Just before one thread terminates a new one starts, to be in like manner followed by another. The tubes are only capable of slight extension, and, when unduly stretched, the membrane ruptures, and the spiral is drawn out singly (as at *d*, Fig. 6), or a band of four or five threads will separate for a few turns (as at *b*). The slenderness of the smallest of these tubes, which have neither interior cuticle nor spiral thread, is as remarkable as their number, and the microscope, even at its best, is barely able to trace out their terminations. Of such, a bundle containing a quarter of a million, would scarcely exceed in bulk an ordinary human hair.

In bees, as in all actively flying insects, the tracheæ are accompanied by large air sacs (*a*, Fig. 6), which are developed in the same manner as the tubes themselves, but carrying scattered venations instead of spiral thickenings of the membrane. In the larval state of comparative inactivity no aerial sacs exist, but they are brought into being during the chrysalis changes. These air sacs have much to do with flight, in a way to be explained when we treat

of the wings, while their forms are such, that no drawing professing to embrace them all could do more than give an inadequate idea. The main ones, in the worker and drone, lie in the anterior part of the abdomen, on each side, communicating with the spiracles; but in the queen they are greatly reduced, to give room for the ovaries.

The spiracles are simple in the larva (*sp.*, Fig. 4), and twenty-two in number (on each side ten well-developed and one rudimentary, the latter vanishing altogether before the last moult. The oft-repeated statement that they are eighteen in all is an error). In the adult, they are more complex, capable of voluntary closing, and so arranged that foreign bodies cannot accidentally enter, while their number is only fourteen—five on each side of the abdomen, and one behind the insertion of each wing. During the period of pupa-hood some of the rings possessed by the larva disappear, while the spiracles they carried vanish. Hence, the adult bee has fewer than the grub, whence it came. In the drone, the spiracles are much stronger and larger, and so more easily studied than in the worker. They are furnished with an apparatus to add to the noise of the insect's flight, which will be more fully noticed by-and-by, are surrounded by delicate protecting hairs, to save them from dust, and number sixteen, in consequence of the drone having an additional abdominal segment. The normal respirations of the bee, when at rest, varying from twenty to fifty per minute, are much influenced by external temperature, by the activity of the stock, and by the amount of

heat it may be necessary to maintain so as to best suit the condition of the brood chamber.

Although insects, and bees in the number, have no general system of blood vessels, as I just now said, they still have a beautiful apparatus by which their fluids are continually carried round and made in purity to visit for nourishment and renewal every part of the body. Their heart, or blood pump, is called, on account of its position, the dorsal vessel, for it runs as a complex tube (*dv*, Plate I., and Fig. 8) along the back, almost immediately beneath the external skeleton. This heart may be seen in action in almost every caterpillar, where the opening and closing of the ventricles, as they are called (*v*, Plate I.), can be watched through the semi-transparent skin. If we are fortunate enough to possess a microscope, we may very easily see the pulsations far more beautifully in the tiniest of the larvæ. Remove from its cell with a blunt needle the smallest to be found, place it on a glass slip, add a drop of water, and, with gentleness, a thin cover glass, when the transparent larva will show, with an inch objective, many wonders beside its spiracles and tracheæ, digestive tube, and nerve system, with the dorsal vessel continuing for some time to gently pulsate. Without a microscope, a little manual dexterity will make the movements of the heart visible in the adult bee. If one accidentally injured is not at hand, a victim to science must be decapitated, and then opened on the under side of the abdomen, so as to remove the stomach and expose the mere back shell seen from within, as Fig. 8 will

make clear, when sharp eyes, or weak ones with a lens, will detect rhythmic throbbings, continuing long, and moving from behind forwards, driving the blood towards the head, much as water rises through the throat of a drinking horse. The walls of this heart consist of three layers—an internal cuticle, a central layer of muscular fibres, $\frac{1}{20000}$ in. in diameter, and an outer coat of connective tissue. In the worker and queen, the dorsal vessel has five ventricles, or contractile chambers, corresponding to the five spiracles on each side. As it nears the thorax, the muscular and internal layer now formed into a conducting tube, bends upon itself three or four times from side to side (Plate I.), by which I imagine the rhythmic beats are converted into a steady and equal discharge of blood in the head beyond, where the tube opens near to the brain. The vitalising fluid returns by soakage through the body to the posterior part, where it re-enters the dorsal vessel. The ventricles are in valvular communication, while each one has on its sides two openings (*dv*, Fig. 8), so contrived that, as the muscular coat is causing a ventricle to dilate, blood enters by them, the valve in front at this time closing, as Plate I. will explain. When contraction begins, an internal fold of the wall of the ventricle closes the side apertures, and drives the blood through the communication into the ventricle in front, and in this manner the forward stream is maintained. The dorsal vessel is braced to the dermal skeleton by surrounding muscles, while beneath runs an extension of muscular plates (*d*, Fig. 8) of most involved character, forming a

horizontal diaphragm or division wall separating the abdomen into two very unequal parts, the larger of which is below.

This diaphragm* in contracting increases the upper cavity and diminishes the lower, and so pressing together the viscera, drives from them blood, which now enters the heart chamber or pericardial cavity (*pc*, Fig. 8), by apertures in the diaphragm itself.



FIG. 8.—CROSS SECTION OF ABDOMEN OF WORKER BEE (Magnified Eight times).
dv, Dorsal Vessel; *d*, Diaphragm; *pc*, Pericardial Cavity; *sp*, Spiracle; *tr*,
Tracheae; *ls*, Tracheal Sac; *st*, Stomach; *n*, Nerve; *ga*, Ganglion.

The dorsal vessel presents many microscopical curiosities; it rests upon a cushion of pericardial cells, with singular nuclei, and which sometimes send extensions either into the outer layer of the heart or the diaphragm. We also find here lobes of fatty bodies (*corps gras*), containing here and there the *cellules enclavées*, or separate cells of Graber, of yellow colour, with a single nucleus, and which resists the action of acids and alkalis, and, beside, multitudes of nerve filaments, and some exceedingly fine ramifications of the tracheal system.

* This diaphragm has been investigated by Graber (*see* "Archiv für Anat. microscop de Schultz," vol. ix., p. 129).

The blood of the bee is colourless, and contains but few corpuscles, which are always white, and carry a nucleus surrounded by granular matter, and have the wonderful though not unusual quality of constantly changing their outline, whence they are called amœboid. At one moment they will be round, but slowly they become ellipsoid, and then, perhaps, an irregular boat shape, or even star-formed.

Our subject is so vast that space can hardly be spared for the discussion of exploded theories; but some mention must be made of the so-called "peritracheal circulation," a pet notion with M. Emile Blanchard. It was supposed that the blood was carried along the tracheæ, between their two walls. The idea was based upon a misunderstood experiment, and the microscope gave no countenance to it; it may now be regarded as beyond resuscitation. The *coup de grace* was administered in Graber's explanation of the functions of the diaphragm, which has removed a great difficulty, as it is now seen that the blood in the pericardial cavity is enriched with oxygen, by the numerous fine tracheæ there placed, and sent in best condition into the dorsal vessel to supply first the brain, and then, in turn, every part.

The muscular system, by which all movements are brought about, depends for its action upon nerve, which induces a contraction, bringing nearer together the parts attached to the extremities of the fibres building up the muscle. The individual fibres, parts of two of which are represented in Fig. 9, are very varied in size in bees. The largest with which I am acquainted are those forming the powerful muscles

enabling the drone to contract the abdomen so as to produce the expulsive act. One of these fibres, when shortened and thickened (as at *a*, Fig. 9), may measure $\frac{1}{400}$ th of an inch in diameter, while the relaxed portion of the fibre is about $\frac{1}{700}$ th. If this muscle be skilfully and quickly removed, and placed either in the fluids of the animal or in a little weak salt and water, upon the microscope



FIG. 9.—MUSCULAR FIBRES OF DRONE (Magnified 300 Times).

a, Part of Fibre, contracted ; *b*, Part relaxed ; *tr*, Trachea ; *n*, Nerve.

stage, the wave of contraction may be seen playing along the fibre, almost as one observes it in a garden worm, as it draws up the hinder part of the body whilst moving onwards. The part (as at *b*) quickly, by bringing together its plates, assumes the appearance of *a*, while *a* extends itself, plate by plate, until it is fully relaxed. The contraction soon ceases, but I have watched it in operation for at least two minutes. Nerves (*n*, Fig. 9)

occasion this exceedingly beautiful rhythmic movement. Those desiring to study it, had better first try the common gentle, its muscles not coming to absolute rest till nearly half an hour after removal from the body. Muscular fibres under a low power of the microscope are easily recognised, on account of their considerable size and striated (cross lined) appearance. They are each covered by a remarkably attenuated membrane, called sarcolemma, in which, generally, a delicate tracheal tube takes its course. Indeed, in the muscles of the wings every fibre has its own particular tracheole (small trachea). The muscular fibres, in this case, lie side by side, and are arranged in bundles (fasciculi); across these pass air tubes, parallelly arranged, which give off from their sides these tracheoles at singularly regular intervals, the latter being equal to the diameter of the fibres. Each tracheole then follows the path of the fibre opposite to it with the uniformity of the rungs of a ladder. This wonderful structure, like every other, could not be properly examined without making us feel that beauty in Nature is something more than skin deep. Most muscles in the bee are attached direct to some portion of the external skeleton, and, where distant parts are thus to be connected by small muscles, tendons are added, as we see in Fig. 10, which represents the apparatus for opening and shutting the jaw; here all the muscles have tendons, two of which are exceedingly long. The striated fibres are attached to the flattened terminal portion of the latter, and are arranged in a plumose form, as seen in the illustration.

How full of wonder and beauty is all this. A bee runs into the hive, but it can only do so because nerves stimulate, and a large number of muscles, each containing many fibres, respond in accurate order, for no joint of a single limb but moves as it ought in obedience to the directing nerve-centres within the



FIG. 10.—JAW OF QUEEN, WITH MUSCLES (Magnified).

lfm, Lesser Flexor Muscle; *gfm*, Greater Flexor Muscle; *lem*, Lesser Extensor Muscle; *em*, Extensor Muscle; *m*, Mandible; *n*, Notch; *og*, Gland System (the Olfactory Gland of Wolff).

insect. How quickly movement follows upon movement, every step involving a complete circle of changes. How tiny the muscles, how impalpable the nerves, and yet large are they in comparison with some others to be found in the same family of

insects. The Anaphis, by example, possesses, like the bee, its six legs, with nine joints each, its four wings, and twelve jointed antennæ, each supplied with its proper muscles and nerves, and almost throughout its structure part for part with its larger relative, and yet its entire weight is less than $\frac{1}{100000}$ th of a grain. What of its egg, carrying within its shell all the directive essentials for evolving these pigmy marvels? The grandeur of the minute will as successfully hush to silence the thoughtful man as the grandeur of the vast.

CHAPTER IV.

NERVE SYSTEM.

Ganglionic Chain—Supra-oesophageal Ganglion—Reflex Action—Commissural Fibres—System of Larva and Imago—Coalescence and Atrophy of Ganglia—Cephalic Ganglia—Convolutions—Pedunculated Bodies of Dujardin—Relation of Size of Brain to Intelligence—Inferiority of Queens—Stomato-Gastric and Sympathetic Systems—Variety of Nerve Work.

THE nerve system in insects (A, B, Fig. 11), whether in the larval or adult stage, consists mainly of a series of rounded masses of brain-like substance, arranged in the median line of the body, near to the lower, or ventral side. These masses, called ganglia* are united by two threads, seen in the figure, and each of which is shown by the microscope to consist of a sheath, having within it an immense number of nerve fibres, serving to bring the separate ganglia into union, by carrying impressions received by one to all the rest. The front mass of all is not on the

* Greek, γαγγλιον, a knot, or excrescence.

ventral side of the body, since the ganglion below it (Fig. 12) sends off two short and curved straps (really nerve bundles), called the œsophageal collar, which embraces the œsophagus, or food passage, *above* which the front mass, or brain, lies, denominated, in

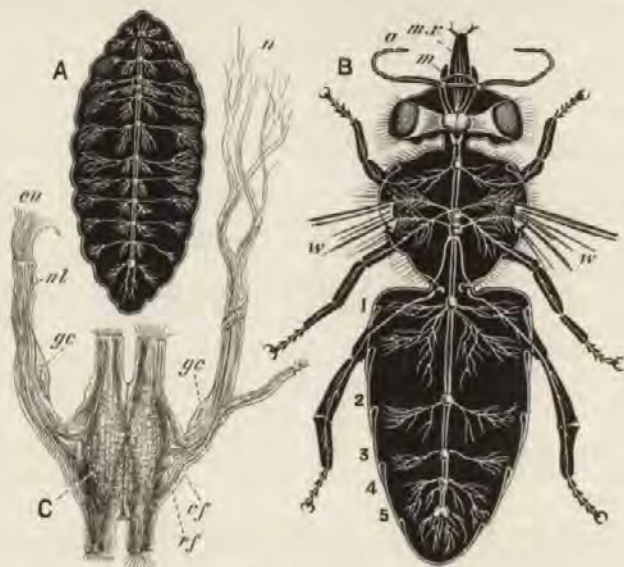


FIG. 11.—A, NERVE SYSTEM OF BEE LARVA; B, NERVE SYSTEM OF ADULT OR IMAGO (Magnified Sixty times); C, GANGLION (Magnified Sixty times).

a, Antenna; *mx*, Maxilla; *m*, Mandible; *w*, Wing; 1, 2, 3, 4, 5, Ganglia; *n*, Nerves; *eu*, Nerves escaped from Sheath; *nl*, Neurilemma; *gc*, Ganglion Cell; *cf*, Commissural Fibres; *rf*, Reflex Fibres.

consequence of its position, the supra-œsophageal ganglion. From reasons presently to engage our attention, it is clear that this ganglion is the seat of intelligence, and that impulses from it dominate the rest, but that the latter are also capable, undirected, of initiating properly concerted movements. A study

of this ganglionic chain gives us the key to many facts, which must puzzle the apiarian who has not become so overpowered by mystery that he has ceased to inquire into the cause of anything.

Unfortunately, even in our humane system of bee-keeping, the tiny throng handled by such a Brobdingnagian race as we relatively are, must now and again meet with serious accidents, and we may have to watch, with mingled astonishment and regret, the rapid march of a headless victim, or the threatening twisting of a detached abdomen, as its sting turns to our finger, striving to execute the *lex talionis*. By looking to our illustration, we see that the decapitated one is still possessed of much brain substance, distributed through the body, and that the isolated abdomen carries with it not less than five ganglia, brain portions, so to speak, which initiate movements simulating design, as we have seen. The loss of the head, although it absolutely puts an end to whatever amount of consciousness the insect possessed when uninjured, reducing it thereby to the condition of a machine, is not fatal, in a restricted sense, as we have already hinted; and, curiously enough, drones in confinement will sometimes live very much longer without their heads than with them. After decapitation, when the irritation set up by the cut has subsided, they will remain perfectly quiet, but immediately they are disturbed they begin to move, running about, and possibly attempting to fly. If the body is turned over, a struggle is made to adjust it, and a hair-pin, dipped in phenol or ammonia, or any substance emitting an irritating vapour,

brought near to one side of the body, will immediately cause the residue of the insect to retreat in the opposite direction. If the hair-pin be actually put into contact with the body, the legs will at once be set to work to rub from the part the cause of annoyance. Facts like these are well known to physiologists, and those who desire to extend their acquaintance with them are referred to such works as Dr. Carpenter's Manual, or Huxley's Text-book.

At Fig. 11 (C), we have an enlargement of one of these ganglia, which shows it to be really double, one-half belonging to the right, and the other the left, side of the body. Let us suppose the lateral threads (*n*) (which are turned upwards, for the sake of convenience, in the illustration) to be provided to the right front leg. If this member be pinched, touched, or influenced in any way, an impression travels along the nerve until the ganglion is reached, when the fibres take four independent courses, all indicated in the figure—some run forwards towards the head, others backwards towards the relatively posterior nerve masses, still others to the opposite half of the ganglion, thus uniting in the impression the right and left sides—such are called commissural fibres (*cf*, Fig. 11); and others, again (*rf*), after entering the mass of the ganglion, and coming into contact with its cells, return by the same side. The impression produced immediately results in a movement, reflected from the ganglion, without any intervention of the action of the brain, and so such movements are called reflex. The commissural fibres would originate action on the opposite side of the body, while the fibres

running forward and backward would bring neighbouring ganglia, and possibly the brain also, into play. Singular as this may appear to be, it is exceedingly like that which is constantly occurring within ourselves. If, by example, an unfortunate soldier has a shot wound dividing his spine, near to the middle of its length, the whole of the lower part of his body will be absolutely paralysed; he will be deprived of both sensation and voluntary movements in his legs. But if, now, his feet be tickled by a feather, although he will feel nothing and know nothing of what is occurring, unless informed by the eye, his legs will plunge violently, and strive to remove the feet from the source of titillation, because the irritation will be carried by his leg nerves to those nerve cells of the spine which are below the injury, and which exceedingly resemble the ganglia of the insect; and from these impulses are reflected, resulting in energetic action, with which his brain has, of course, nothing to do, precisely as in the case of the decapitated drone, which will by its legs forcibly push from it a cause of annoyance, if such a word may be employed in relation to that which has no consciousness. Without going to so dread an example as a wounded soldier, we may constantly trace in ourselves, or our friends, movements which are purely reflex, resulting neither from a sensation nor a mental impression, but made, possibly, in the absence of both.

Nothing can be more striking than the difference between the arrangement of the ganglia of the bee larva and that of the same insect in the perfect condition, unless we take into account the exceed-

ingly diverse circumstances of the life of the two, the helpless dependence and quietude of the former standing in marked contrast to the self-sacrificing devotion and restless energy of that of the latter. The changes, which fit the same nerve system for such opposite conditions of being, are effected by slowly-made modifications, commencing with the creature's independent existence, but which are more active and radical during the chrysalis, or pupal stage.

The business of the larva is to eat. It is produced from an egg, which must be tiny, because the mother laying it furnishes others in such prodigious number. The minute body it possesses, when its first pap is given to it, must increase in weight, as I have found by careful experiment, about 1400 times during the four days it feeds; and so its nerve system is now principally distributed to its digestive apparatus and to its spiracles. It claims, as yet, neither legs, wings, nor eyes; nevertheless, during the period that the one want of its lower existence is being met, preparation is also being made for the higher endowments, new responsibilities, and enlarged enjoyments of the future, for its nerve masses are already coalescing, in order to become more perfect in their functions; they are concentrating their influence and making the insect less vegetative. The larva has seventeen embryonic ganglia (as seen in Fig. 13), one supra-œsophageal, three sub-œsophageal—that is, under the œsophagus, and also under the first-mentioned ganglion, or brain—three thoracic, and ten abdominal; but, as it grows, and in an early stage, the three sub-œsophageal and three last abdominal

in each case fuse into one, reducing the ganglia to thirteen, as we have them in A, Fig. 11, where, of course, the two first ganglia, lying over one another nearly, appear in actual contact. But when the old digestive tube lining and contents have been cast away (see page 22), and the chrysalis stage is reached, metamorphoses proceed more rapidly. The two latter thoracic and two first abdominal ganglia then unite, forming a large and powerful nerve mass (as seen at B, Fig. 11), still giving indications of its compound origin, and initiating the main external activities of the insect by throwing out, from its anterior parts, nerves to the second pair of legs and the anterior wings, while its posterior half gives, similarly, energy to the third pair of legs and the posterior wings, the front legs receiving twigs from the first thoracic ganglion. The original eight abdominal ganglia, but now reduced to six (see *supra*), suffer a further diminution in number by the fourth and fifth melting together; and so we find, in the worker, five abdominal ganglia, while, for reasons given when treating of the queen and drone, they have four each only. But let us not imagine that coalescence and development are all that occur. The larva had needs which it does not carry with it when it leaves the cell, and so some structures are atrophied, with the nerves supplied to them, while their material, by absorption, is diverted to other uses. These changes require much patient investigation in order fully to trace them, but they may in large part be easily seen by proceeding with eggs and larvæ of various ages, as stated on page 37.

We now pass to consider more in detail the structure of the head, or cephalic ganglia, which should show us the evident relation subsisting between the wants of the animal and those curious endowments which come to it, we know whence, though we know not how, in the quietude and darkness of the little waxen cell.

Looking to Fig. 11, B, we find in the head the upper view of the supra-œsophageal, with the collar uniting it to the sub-œsophageal ganglion, while, in Fig. 12, we have a front and enlarged view of the same. The former ganglion, or brain, is so soft and transparent, that it is hardly possible to trace its form without the use of some hardening agent, such as alcohol, or chromic acid; but for a microscopic examination of the character of its substance we must operate upon a bee in a perfectly fresh state. The upper part of the cranium being removed, we come first upon salivary glands, numerous tracheæ, and tracheal sacs, covering up the brain, which is itself inclosed in a double membrane, like the pia and dura mater of higher animals; these stripped off, we reach the pulpy material of the cerebral mass, consisting, for the most part, of transparent globules, from $\frac{1}{3000}$ th to $\frac{1}{8000}$ th of an inch in diameter. If now we pour over this some solidifying material—and, for popular work, turpentine will answer well—we find it does not become uniformly white and opaque, but convolutions, such as seen at *p*, Fig. 12, begin to make their appearance near to the ocelli, or simple eyes (*o*). By degrees, removing the pulpy mass which covers over these convolutions, we find the latter to be an interior sub-

stance, whiter and more solid, possibly corresponding to the so-called white matter of the brains of vertebrate animals. The general form taken is seen from B, which covers over, but still so as to allow to appear, the so-called pedunculated bodies of Dujardin, and is copied from an actual brain, compared with the drawing given by that physiologist, in his admirable Memoir.* When these bodies are freed from their surroundings, they are seen to bear a very



FIG. 12.—THE BRAIN, OR SUPRA-OESOPHAGEAL GANGLION

A, Head, showing Brain, &c., magnified ten times—*o, o, o*, Ocelli; *a, a*, Antennae, with Nerves; *p, p*, Brain covering Pedunculated Bodies; *og, og*, Optic Ganglion; *s*, Sub-oesophageal Ganglion. B, Supra-oesophageal Ganglion, or Brain, deprived of External Membranes, magnified thirty times.

short peduncle, or stalk, pointing towards, and nearly reaching, the median line; so that, although they do not actually touch, they possibly bring the two lateral halves of the brain into relation. These stalks bear above them the convoluted lobes. A granulous tubercle, placed in front of each of these singular forms, and prominent in the ant as well as the bee, is supposed by Dujardin to be especially

* "Annales des Sciences Naturelles," 3^{me} Série, vol. xiv.

provided to receive the communications made by these wonderful little creatures, by tappings on the front of the head with the antennæ.

Our figure shows that the brain sends three short stalks to the ocelli (*o*), the centre one receiving its nerves from the right and left side, while the brain laterally passes into the two masses provided to the large compound eyes; on each side also, a well-developed lobe, beneath, gives origin to a nerve supplying the antenna, for Dujardin seems to have been in error in supposing that these arose from the pedunculated bodies.

Such, then, is the brain of the bee, declaring that its owner is endowed, at least, with glimmerings of intelligence. For, in those insects whose whole course may be supposed to be simply instinctive, the pedunculated body is not found; in such, the entire brain, and every ganglion, consists alone of pulpy matter. Where the pedunculated bodies exist, their bulk, as well as that of the antennæ lobes, seems to bear a direct proportion to the diversity of action of which the creature possessing them is capable. We have a progression in the size of these appendages as well as in instinctive development in passing—*e.g.*, from the cockchafer (*Melalontha vulgaris*) to the cricket, on to the ichneumon, then to the carpenter bee, and, finally, to the social hive bee, where the pedunculated bodies form the $\frac{1}{2}$ th part of the volume of the cerebral mass, and the $\frac{1}{870}$ th of the volume of the entire creature, while, in the cockchafer, they are less than the $\frac{1}{2300}$ th part. The size of the brain is also a gauge of intelligence.

In the worker bee, the brain is $\frac{1}{174}$ th of the body; in the red ant, $\frac{1}{296}$ th; the *Melalontha*, $\frac{1}{3500}$ th; the *Dytiscus* beetle, $\frac{1}{4400}$ th. And here a very curious point arises. As we proceed, I shall have more than once to point out a misconception, which would appear to be all but universal amongst bee-keepers, and to show that the queen is not superior to, but greatly the inferior of, the worker; and the brain bears evidence to this position, as that of the queen is relatively small, as is also that of the drone. The amazons, who support the political fabric of the bee-hive, supply its food, bring up its young, furnish its architecture, defend its property, administer justice, and determine the how, when, and where of new colonies, require greater endowments than the males, and true female, who is largely aborted, so as to be almost exclusively limited to the faculty of reproduction.

Besides the principal nerve system of which we have spoken—that of animal life—the bee, in common with some other insects, is possessed of two other systems, of less proportions, and more visible in the larva than the adult, which give energy to the functions of organic or vegetative life. One is denominated the stomato-gastric, and is provided with numerous minute ganglia, which send nerve-fibres into the organs of digestion, circulation, and respiration; the other, corresponding probably to the sympathetic of higher animals, has, in each segment of the body, a very small triangular ganglion, sending out threads, which ultimately anastomose with those of the previously considered abdominal chain.

It is exceedingly difficult, nay, rather, impossible, although we are but thinking of the little bee, to realise the wonderful complexity and capability of this brain and ganglionic system, with its countless nerve fibres and numerous nerve cells ever transacting the mystic and involved telegraphy of life, receiving messages and transmitting replies with a quickness as little to be conceived as that of the electric current itself, besides stimulating and co-ordinating a great diversity of parts, and bringing all into a conscious unit, and so endowing that unit, that it is but part of a greater whole, which, in turn, puts itself into true, determinate, and useful relation to the world which forms its environment; but we shall hereafter remember, that no muscle can move, no heart throb, no organ of sense receive an impression, no gland secrete, and no digestion be performed, without the operation of some part of these strange transparent threads, with their accompanying ganglia.



CHAPTER V.

DIGESTIVE SYSTEM.

Need of a Digestive System — Food Solution — Similarity of the Digestive Process in all Animals — Œsophagus—Honey Sac—Stomach-Mouth—Chyle Stomach—Gastric Teeth—Small and Large Intestines — Anal Glands — Embryogeny of Digestive Tube—Structure and Use of Stomach-Mouth and Chyle Stomach—Dufour's Theory.

THE primary object of a digestive system is to supply the vitalising and formative material called blood, which sustains in activity and builds up out of its substance every tissue of the bodies of animals. A little attention given to the process of blood making in our own case, will well prepare the way for a better realisation of the uses of the structures we find in bees. Our food, whatever may be its character, needs at first to be wholly or in part brought into the condition of solution in water, and only such part as is actually dissolved can be in any way utilised; *e.g.*, in ordinary bread, our typical food, we have principally two substances, starch and gluten, both of which may be soaked for any

period without dissolving, if decomposition be prevented; but during the process of chewing or mastication, glands, of which we, like our bees, have three pairs, pour into the mouth, saliva, whose principal office is to chemically change some parts of our food, and notably starch, which, under its action, begins to be formed into sugar, one of the most soluble bodies furnished by the plant world. After swallowing, the process of transformation goes on, until at length all starch has disappeared, and the sugar produced from it has, by absorption, got into the blood current. This sugar, although derived from starch, is still the representative of the honey of the bee, while the gluten, the residue of our bread, is the counterpart of her pollen—so similar are our sources of sustenance. But gluten requires a treatment distinct from that which the starch received, for the former is not materially affected in the mouth, but, passing into the stomach, the gastric secretion acts upon it and so transforms it that a new and soluble material, sometimes called albuminose, is produced, which can be, on account of its liquid condition, transmitted to the blood, and that mainly by the action of a multitude of minute thread-like bodies, which cover the inner side of part of the alimentary tube, and, so to speak, drink up the dissolved, or, in other words, digested, nourishment. This glairy material, thin and transparent, is, after absorption, carried up a narrow channel running in front of the backbone, and poured at length into a vein under the middle of the clavicle (collar-bone) on the left side. Thus mixed with the blood, it is

quickly made into part of that fluid actually, and now, with the rest, visits every muscle and organ by the circulation, in order that it may nourish and sustain. Far removed as we are from bees, there still exists between us and them a most helpful similarity of physical structure, and presently we shall find that the salivary and gastric secretions perform precisely the same functions in both.

If the abdomen be pulled from the thorax of a recently dead bee, until the integument, which is really a part of the external chitinous envelope, ruptures at the narrow junction of the two, called the petiole or stalk, we shall almost uniformly drag away with the abdomen a long thread-like form, which is really the tubular œsophagus or gullet (*a*, Plate I.), running away from the tongue through the head, neck, thorax, and petiole, about $\frac{1}{8}$ in., until it begins to enlarge within the abdomen.

It often happens that the rough surgical operation just described will pull the digestive tube from the abdomen, as well as expose the œsophagus; but, if not, but little skill is required in so opening the body that the whole may be removed without much injury to it.

Certain glandular products are added to the food in the mouth, of which more hereafter; but the œsophagus is only conductive in character, and is narrow within the thorax, being $\frac{1}{80}$ in. in diameter. The thorax, indeed, as the centre of locomotion, is loaded with the strong muscles the legs, and especially the wings, require, and so here no space can be spared for the function of digestion. The enlarge-

ment just referred to (*hs*, Plate I.) is known as the honey sac, and corresponds to the crop of most insects. It is about $\frac{1}{8}$ in. in depth and $\frac{1}{8}$ in. in diameter when full of honey, of which it will hold a full third of an ordinary drop. When nectar is gathered by the foraging bees, it is simply held in store in this cavity, the processes of digestion in no true sense beginning until the next chamber (*cs*)—the chyle stomach—is reached. The bee having returned to the hive, the cross muscles indicated in *hs*, Plate I., and LM, TM, Fig. 14, by contraction, press upon the contained nectar and drive it back through the œsophagus into the cell of the comb, in the manner described at page 18. But, if the mouth of the ox that treads out the corn should not be muzzled, it is clear that the little labourer should have an opportunity of taking, of that it has gathered, for its own support. To permit of this and much more, a rounded body (*p*, Plate I.), of singular and beautiful structure, about $\frac{1}{10}$ th of an inch in diameter, is placed at the bottom of the honey sac. It can be easily seen by the unaided eye, and is of pearly, yet brownish, colour. This apparatus (which may be more easily investigated in the Queen *Bombi* than the hive bees, on account of its greater size in the former) we shall carefully examine presently, at the moment calling it the "stomach-mouth," a very appropriate name, which Burmeister has given, and which sufficiently explains its use, for the bees' food can be taken through it at will, and as required, into the chyle stomach. The latter bends much upon itself in the worker, has a diameter of $\frac{1}{10}$ in. and a length

of $\frac{2}{3}$ in., but is straighter and smaller in the queen, and its sides are, in all cases, banded with constrictions that occur at regular intervals. The gastric glands are placed in its walls, while the pollen grains commonly found within it in abundance give to it a yellow, or yellowish-brown, appearance. At its further extremity it narrows considerably, and forms a pylorus in passing into the small intestine (*si*, Plate I.), which is here met by a considerable number of long and narrow tubes (*bt*, Plate I.), lying in tangled spirals, but which, nevertheless, enter the walls of the digestive system with great regularity, their openings being closely set, side by side, in a single encircling line. They are, probably, excretory in function, removing, like the liver in ourselves, impurities from the blood, which are modified so as to be of service in the work of digestion. Their structure is shown at C, which gives a small portion of one of them, magnified 450 times. These tubes are known as Malpighian vessels, from the great anatomist, Malpighi, who discovered them; or are called biliary or urinary tubes, according to the view which may be taken of their office. The intestinal lining membrane here undergoes an interesting modification; it is arranged in a number of longitudinal ridges, and is set with small, though hard, chitinous teeth (*D*, *gt*, Plate I.), frequently double-pointed, each about $\frac{1}{2500}$ in. in length. They are most easily seen in a newly-hatched bee, before any food has been taken to interfere with the view. The object of these, in my opinion, is to abrade the growing points of any pollen grains which have not sufficiently yielded

to the action of the chyle stomach, so that their nutritious contents may be duly appropriated. To enable them to accomplish this, a strong coat of ring muscles is provided, thus equipping the bee with a rudimentary gizzard, beyond which the small intestine lies, somewhat twisted, and not quite uniformly placed in different bees; its diameter, which varies little throughout its length, is about $\frac{1}{30}$ in. It is shown in cross section in D, Fig. 14. The muscles supplying it are remarkable, and may be conveniently studied under the microscope after staining with eosin, or even ordinary red ink. The colour of its contents is perceptibly darker than that of the chyle stomach, while the pollen grains, which in the former are but little altered, are here generally damaged in the cellulose cover (see page 10), and are frequently broken up completely, as they have had to pass the mill of the gastric teeth. The small bowel suddenly, and afterwards more gradually, expands into the colon, or large intestine (*l*, Plate I.), which is often swollen and dark in appearance, because its transparent and colourless sides show clearly its contents, which have here that disagreeable odour too well known to bee keepers who have given liberty to bees that have endured the confinement and worry of a long journey. At the commencement of the colon are placed six longitudinal, brownish, fleshy plates (*l*, Plate I.), which appear to be both valvular and glandular in action; they are protuberant on the inner side, and are formed by an invagination of the intestinal walls, the whole of the layers of which

take part in their structure. Tracheæ densely ramify in these tubercles, and a large nerve is supplied to them. M. Leydig compares these fleshy plates to the tracheal lamellæ forming the rectal branchiæ, or gills, of the aquatic larvæ of the libellulidæ, or May flies.

Embryogeny (the science of the development of embryos) shows that, whilst the bodies of insects are being fashioned within the egg, the digestive tube is formed in three parts, as follow: The mouth and anal extremities by invaginations (see page 34) of the external skin, the central portion from a modification of the yolk sac, which is met at its ends by the continued deepening of the posterior and anterior invagination. The parts have now no communication, their ends being blind, but are placed like two half sausage skins, with a whole skin in the centre. The separating walls at length undergo absorption, and the tube becomes single and united, passing through the body from end to end; the annexed organs are then marvellously added to this simple tube, which forms gradually, at definite spots upon its wall, prolongations, at first like the fingers of a glove, but by degrees assuming the involved structure they possess in the adult insect. In this manner within the bee egg the spinning glands (Fig. 15), which subsequently become System 3 of the salivary glands (Fig. 16), are formed at the anterior part, and at the posterior, similarly, the Malpighian, or urinary tubes. An arrested development, however, in bees, hornets, and wasps, causes the middle

bowel to remain blind at the posterior extremity, which may be well seen at Fig. 13, representing the developing larva within the egg membrane; here the anterior invagination (*fb*) has already made junction with the middle bowel (*mb*), but the after bowel (*ab*) remains separate, and will continue to do so until the commencement of the chrysalis condition, so that the larva, usually so prolific of dejections, in the case of the above-mentioned insects passes nothing. If it were otherwise ordered with bees, by example, the embarrassment would be great where the larva lies



FIG. 13.—BEE LARVA BEFORE HATCHING (Magnified Forty times).

ch, Chorion, or Egg Skin; *ga*, Ganglia; *s.ga*, Supra-oesophageal Ganglion; *jm*, Jaw Muscles forming; *c*, Nerve Collar; *fb*, Fore Bowel; *mb*, Middle Bowel; *ab*, After Bowel.

in a cell surrounded on all sides by liquid food; besides which, the honey we now so much value would be made unacceptable, through possible contamination from an uncleanly nursery. I have already explained my discoveries respecting the way in which the accumulated residua are at length got rid of so as to leave the larva unsullied (page 22). These surprising changes, humbling us by showing us how little we know, and how much there is to learn, may, without difficulty, be witnessed by those possessing a stock of bees to furnish eggs, and

a microscope to examine them. Let us now investigate in detail the stomach-mouth and chyle stomach.

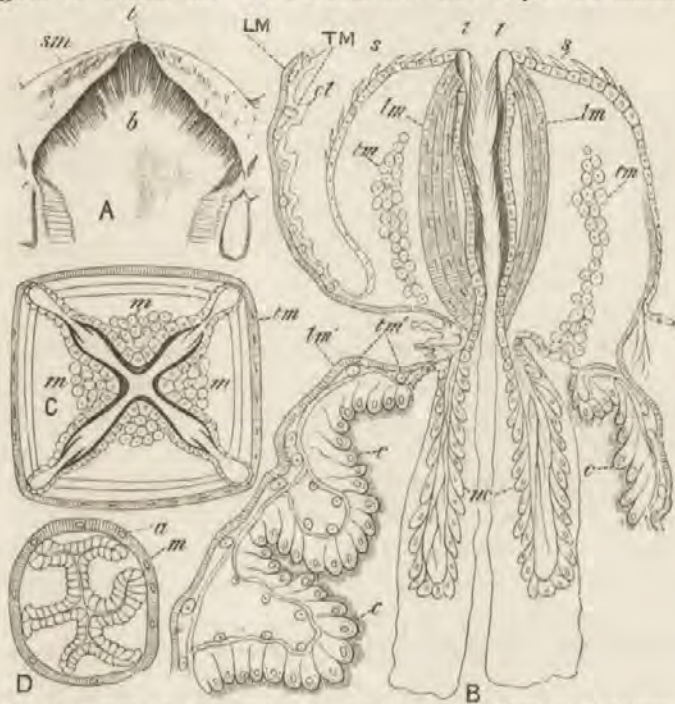


FIG. 14.—HONEY SAC STOPPER, OR STOMACH-MOUTH, &C. (Magnified Fifty times).

A, Front View of One of the Four Leaflets of Stopper, or Stomach-Mouth—*l*, Lip-like Point, covered by Down-turned Bristles (*b*); *sm*, Side Membrane. B, Longitudinal Section of Stomach-Mouth, with Continuations into Entrance of Chyle Stomach—*l, l'*, Lip-like Ends of Leaflets; *s*, Setae; *lm*, Longitudinal Muscles; *tm*, Transverse Muscles, in Cross Section; *cl*, Cell Layer of Honey Sac; *LM* and *TM*, Longitudinal and Transverse Muscles of same; *nc*, Nucleated Cells of Tubular Extension of Stomach-Mouth into Chyle Stomach; *lm'* and *tm'*, Longitudinal and Transverse Muscles of Chyle Stomach; *c, c*, Cells covered within by an Intima. C, Cross Section of Stomach-Mouth—*m*, Cross Section of Muscles seen at *lm* in B; *tm*, Transverse Muscles surrounding Stomach-Mouth. D, Cross Section through Small Intestine—*a* and *m*, Longitudinal and Surrounding Muscles.

We have already learnt that the first of these enables the bee to store honey, which, although

G

carried within her body, does not enter her digestive system, and that by the means of it food can be taken into the chyle stomach as required. *p*, Plate I., shows us the stomach-mouth, as seen through the transparent walls of the honey sac, its form being not unlike an unopened flower-bud with four sepals. If it be carefully removed from a recently-killed bee, and examined by a simple lens, its lips or leaflets may frequently be observed opening and shutting with a rapid snapping movement. A more remarkable object than this under a low power of the microscope can scarcely be imagined. The œsophagus, honey-sac, and chyle stomach, should be removed together, and placed on a glass slip, the microscope stage being made horizontal. No cover glass should be used, but sufficient very weak salt and water added. The whole object will exhibit, for at least fifteen minutes, muscular contractions of a most instructive kind, while the gaping and snapping of the stomach-mouth, and the passing onwards of food, is often noticed. If the bee operated upon has just previously been fed with honey stained with some aniline dye, the effect is enhanced. By closing the œsophagus I have frequently succeeded in getting, not only food, but even bubbles of air, gulped down into the chyle stomach, and, by carefully pressing upon the stomach-mouth with the side of a needle, the lips may be forced open, and food passed on into the stomach beyond. One leaflet being separated from the rest, we find it strongly chitinous within, and fringed along its margin (A, Fig. 14) by downward-pointing, fine, but strong bristles. At B we have the longi-

tudinal section of the whole apparatus, with its entrance into the chyle stomach, somewhat as figured by Schiemenz.* It is provided with two sets of strong muscles, one (*lm*) running perpendicularly along the backs of the leaflets, and, by their contraction, pulling asunder the lips, and permitting a passage of food from the honey sac to the chyle stomach; another (*tm*), in cross section in the figure, running round the whole, and perfectly closing it at the will of the bee. The figure in like manner shows the two muscular layers (LM, TM) of the honey sac, by the united contraction of which the gathered nectar is driven out into the cells of the comb for general consumption. C, as it gives the form in horizontal section, with the opening and closing muscles, makes somewhat clearer the beautiful mechanism of the stomach-mouth, the utility of which is so conspicuous: for the bee can eat whenever and wherever she likes: when she departs from the old home, with all its stores provided against a "rainy day," and commits herself, with her companions, to the vicissitudes which the swarm must encounter, she can minimise her risks by carrying, in the honey sac, sufficient food for a week's necessities, either using it rapidly in the production of wax, or eking it out, should the elements prove unfavourable for the gathering of new supplies; and in winter, when departure from the cluster is impossible, she can, at infrequent intervals, as opportunity arises, so charge herself from the honey cells

* See "Über das Herkommen des Futtersaftes und die Speicheldrüsen der Biene."—"Zeitschrift für Wissenschaftliche Zoologie," Band 38.

that her wants will always be supplied, and her ability to produce heat be uninterrupted.

But, besides these beautiful adaptations, another use has been suggested. Léon Dufour taught that the larvæ of bees are nourished by an ejection into their cells of semi-digested food from the chyle stomach of the nurses, and this idea, unsupported as it is by evidence, has gained all but universal acceptance. Schonfeld* explained the stomach-mouth in conformity with this opinion, but recent investigations have more than ever convinced me of the erroneous nature of Dufour's theory. Schonfeld at first altogether failed to observe that the stomach-mouth is prolonged into the chyle stomach by a tube containing a layer of nucleated cells (*nc*, B, Fig. 14), beyond which extends an extremely delicate membrane (*intima*), which Schiemenz is confident can have no other object than to prevent the return of digesting matters into the honey sac, his opinion being that, except when food is passing through it, this tube must collapse completely, being pressed on one side, and flattened. But microscopic examination and experiment have shown me that, although the tube of *intima* interferes with regurgitation, as Schonfeld is forced to admit, still it may float in the stomach, and preserve its cylindrical form notwithstanding pressure, so that its presence rather makes regurgitation improbable than impossible. Schonfeld has also left unnoticed the down-pointing bristles (*l*, A and B, Fig. 14), which would, by straining,

* See translation in *British Bee Journal*, 1st July, 15th Sept., 15th Oct., and 1st Dec., 1883.

effectually prevent the passing upwards of any solid particles, such as pollen grains, whole or broken, even could the difficulties previously mentioned be overcome.

But it will be seen that these explanations are partly negative, giving us no reason for the presence of either tube extension or down-pointing bristles, since a mere sphincter (or ring of closing muscles) would, by contraction and relaxation, have either totally prevented regurgitation, or permitted it, if necessary, and also have enabled the bee to take such food from the honey sac as it might at the time being contain. It is clear, then, that either parts have been added which are not requisite, or that some function exists which has hitherto escaped observation. Surely it is the latter. Dissecting bees from the hive, young and old, ordinary nurses and queen grub feeders, starved and fully fed, gave me no help in this matter, beyond showing the extraordinary complexity and variety of movement of which the stomach-mouth is capable; but those that were engaged in gathering yielded the solution.

On the *Compositæ*, as well as many other orders, bees suck up nectar, in conjunction with much pollen, and, examining the honey sac of one working upon a single dahlia, *e.g.*, the outside wrinkled membrane (*sm*, A, Fig. 14) is seen to continually run up in folds, and gather itself over the top of the stomach-mouth, bringing with it, by the aid of its setæ, the large pollen grains the nectar contains. The lips (*l*, *l*, B, Fig. 14), now opening, take in this pollen, which is driven forwards, into the cavity made

between the separating lips, by an inflow of the fluid surrounding the granules. The lips in turn close, but the down-pointing bristles are thrown outwards from the face of the leaflet, in this way revealing their special function, as the pollen is prevented from receding while the nectar passes back into the honey sac, strained through between the bristles aforesaid, the last parts escaping by the loop-like openings seen in the corners of C, Fig. 14. The whole process is immediately and very rapidly repeated, so that the pollen collects, and the honey is cleared. Three purposes, in addition to those previously enumerated, are thus subserved by this wondrous mechanism. First, the bee can either *eat or drink* from the mixed diet she carries, gulping down the pollen in pellets, or swallowing the nectar, as her necessities demand. Second, when the collected pollen is driven forwards into the chyle stomach, the tube extension, whose necessity now becomes apparent, prevents the pellets forming into plug-like masses just below *p*, Plate I., for, by the action of the tube, these pellets are delivered into the midst of the fluids of the stomach, to be at once broken up and subjected to the digestive process. And third, while the little gatherer is flying from flower to flower, her stomach-mouth is busy in separating pollen from nectar, so that the latter may be less liable to fermentation, and better suited to winter consumption. She, in fact, carries with her, and at once puts into operation, the most ancient and yet the most perfect and beautiful of all "honey strainers."

The chyle stomach is lined by an intima, or inner

membrane, carrying a cell-layer (*c*), the cells composing which appear to be of two kinds, having distinct functions, one secreting a digestive fluid (gastric juice) from the surrounding blood into the stomach, so that the contents of the pollen grains may be made fit for assimilation, by a transformation not unlike that liquefying gluten in our own case; the other absorbing the nutrition as prepared, and giving it up into the blood—these cells representing the absorbent vessels of ourselves and the higher animals generally. Outside this cell-layer comes a propria, or outer membrane, and, beyond this, two muscular coats, one (*tm'*) of ring muscles, the other (*lm*) of longitudinal muscles, which, by their appropriate contractions, originated by the stomato-gastric nerve system, churn the contained food, and move it onwards past the several constrictions previously mentioned, and which are commonly twenty-three in number, until the pyloric extremity is reached. The process of absorption continues in the intestines till only waste products and indigestible matters remain, and these are ejected by a muscular action, which can only be effectively employed, in the case of the worker and drone, when the insect is on the wing. The queen presents an exception to this rule, which will, hereafter, require an explanation.

The view here suggested, that the brood is not nourished by regurgitated material, leads at once to the question, How, then, is it fed? No satisfactory answer can be given until we study the gland structures.

CHAPTER VI.

SALIVARY (?) GLANDS OF BEES.

Discovery of Glands—Plans for Dissection—Position and Connection of Systems No. 1, No. 2, No. 3—Details of the Systems—Intracellular and Inter-cellular Glands—System No. 4 of Schiemenz—Uses of the Glands—Variations in Queens—Brood Food—Brood Weaning—Royal Jelly—Queen Raising—Fertile Workers—Egg Production—A New Theory Respecting Queen Food—Queen Dejections—How Queens are Stimulated into Laying by the Nurses—System No. 1 a Chyle Gland—Retarded Laying Explained—Feeding-Groove.

IN 1811, Ramdohr announced the discovery of a pair of salivary glands in the thorax of bees, whilst two other pairs were found by H. Meckel, in 1846; and yet dense ignorance respecting them is common to the present day, even such an accomplished German apiculturist as Berlepsch failing to mention them, while Cook only in his last edition (1884) calls attention to the existence of *two* pairs, which he tells us were "first discovered by Mr. Justin Spalding." It is not a wonder that the rank and file of

bee-keepers are as much in the dark as those to whom they look for leading. Leydig* and Siebold† did much to elucidate the structure of these glands, but their methods of dissection were not sufficiently refined to enable them to properly locate them in the body of the bee; Siebold, in particular, falling into serious mistakes on more points than one, followed by Girard, who does not appear to have himself made any dissections.

It has already been stated that the larva secretes its cocoon from a gland, which reappears, in a

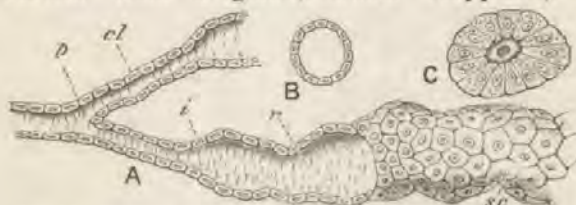


FIG. 15.—SILK GLAND OF BEE LARVA (Magnified Eighty times).

A, Gland—*p*, Propria; *cl*, Cell Layer; *i*, Intima; *r*, Reservoir; *sc*, Secreting Cells. B, Transverse Section of Reservoir. C, Transverse Section of Secreting Layer, with Interior Lumen, or Cavity.

modified form, in the adult. This gland is seen at Fig. 15. Its product, as is usual with insects, remains perfectly liquid so long as it is stored in the reservoir (*r*), but quickly hardens after it is drawn out into threads, although not so rapidly but that the several filaments where they cross each other partly fuse together, and so much strengthen the gossamer blind which the larva elaborates (*see* Fig. 4). The secretion itself is derived from the blood by the action of the cells (*sc*), seen in the cross section C,

* "Archiv für Anatomie Physiologie," &c., Leipzig, 1859.

† "Mittheilungen über die Speichelorgane der Biene," 1872.

and surrounding a small tube, or lumen. These cells have, of course, an absorbing surface on the outside, while their proximate faces secrete a liquid silk, which, as formed, is passed into the reservoir, of which B is a cross section, where it collects in considerable quantity before the time of spinning.

By inserting a needle into the mouth of a worker bee, and passing it upwards, behind the front wall of the head, the latter may be so opened that its salivary (?) glands, in a partly broken condition, may be obtained for examination; but if the attachments and entire forms are to be investigated, we must proceed as follows: Partly fill some shallow receptacle, such as a pomatum-pot, or large pill-box, with melted bees', or paraffin, wax. When cold, with a hot wire melt a little bath in the centre of the waxen surface, and then insert the bee we wish to dissect, so placing in this case that one side of the head is submerged. By a second application of the wire, re-melt the wax in the neighbourhood of the head, using no more heat than is necessary to secure thorough adhesion, and now cover with water or glycerine. A powerful light and a good watch-maker's eye-glass (secured round the operator's head with a tape, when it can be pushed up on to the forehead if not required) will permit of reasonably good dissection, although, of course, better results can be reached by using a Stephenson's erecting-binocular-microscope—the instrument with which all the dissections for this work have been made. The bee thus securely held by the wax, both hands are free to manipulate. Now, with a needle-

knife (made by heating a large needle, beating it

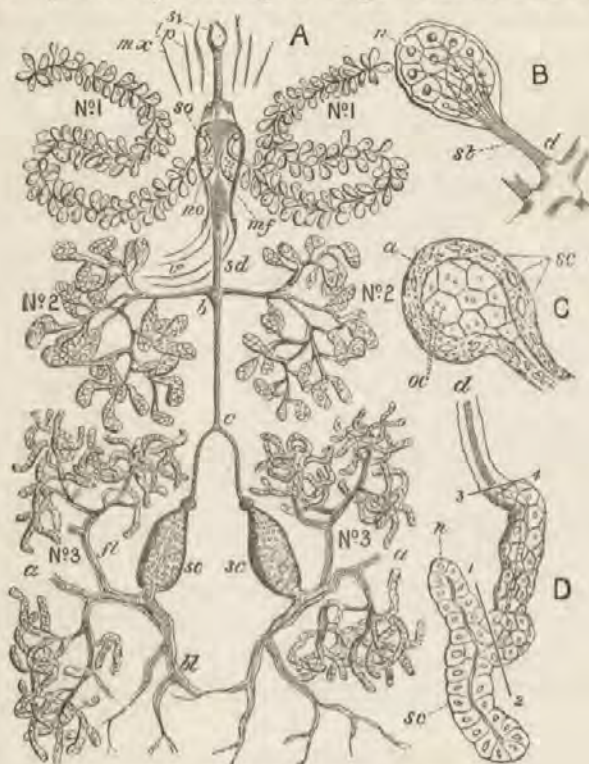


FIG. 16.—SALIVARY (?) GLANDS OF THE BEE.

A, Salivary (?) Glands, Systems No. 1, No. 2, and No. 3, magnified fifteen times—*mx*, Salivary Valve (of Systems No. 2 and No. 3) at Root of Tongue; *b*, Labial Palpus; *mx*, Maxilla; *so*, Salivary Opening of System No. 1 in Hypo-pharyngeal Plate; *no*, Openings in Plate for Termination of Taste Nerves; *ae*, Oesophagus; *sd*, Salivary Duct; *b*, Junction of Ducts of System No. 2; *c*, Junction of Ducts of System No. 3; *sc*, *sc*, Salivary Sacs; *fl*, Front Lobe; *bl*, Back Lobe; *a*, Chitinous Duct, with Spiral Thread. B, Single Acinus of System No. 1, magnified seventy times—*n*, Cell Nucleus; *st*, Salivary Track; *d*, Large Duct. C, Single Pouch, or Acinus, from System No. 2—*a*, Propria, or Outer Membrane; *sc*, Secreting Cells. D, Termination of System No. 3—1 2, 3 4, lines marking Termination of Section; *d*, Duct, in section; *sc*, Secreting Coll, in section; *n*, Nucleus.

flat, and afterwards sharpening upon a hone, and

inserting into a wooden handle), cut carefully round the compound eye, and lift it off. Curiously folded, and passing round the optic ganglion, we have a long whitish body, which a facetious friend compared to ropes of onions. It is one side of the System No. 1 of Siebold (Fig. 16). Behind this, and extending from the top of the head downwards, we find packed inimitably a second gland system (No. 2), consisting of many pouches, joined by canals to a common duct, which may be followed until it is discovered to enter another duct (*b*, Fig. 16) running backwards and forwards in the body. Tracing this channel towards the thorax, we see it enter the neck, and immediately after bifurcate or fork (*c*, Fig. 16). Following the line of one of the two ducts, we come upon a reservoir (*sc*), leading backwards to another gland system (No. 3), of singular structure, with two lobes, lying in the front of the thorax on each side of the body. The position of all these systems is well seen in Plate I. The operation here described is not likely to be accomplished with one bee, and I spent many days, and spoilt many specimens, before getting the glands in their entirety, with their connections; but I have good reason for supposing that these successful dissections are unique. Leaving out of view for the present a fourth gland, attached to the jaw (Fig. 10), and which Siebold failed to note, let us proceed to examine in detail the systems to which he gave name.

Taking pains to secure an entire right or left gland of System No. 1, we find it to consist of an inelastic, transparent, central tube or duct, without branches,

and of the uniform diameter of from $\frac{1}{800}$ in. to $\frac{1}{1000}$ in., surrounded through its length, which is fully once and a half that of the entire body of the bee, by between 1000 and 1200 berry-shaped bodies, called acini, of which one is much enlarged, B, Fig. 16. In these acini the secretion is produced by cells, which develop, perform their function, and pass away, to be succeeded by others. The cells forming each acinus are surrounded by a bag-like membrane, or propria, through which the blood passes continually, to supply the material out of which the secretion is elaborated.

System No. 1 is *intracellular* in type—*i.e.*, every part of the surface of each cell is absorbent, so that the secretion it furnishes has to be removed from its interior by a duct, which enters its wall, becomes surprisingly delicate, and takes within a lengthened, sinuous course, bringing itself in contact with the cell plasma. These chitinous tubes, each about $\frac{1}{18000}$ in. in diameter, after leaving the cells, pass parallelly through an enveloping tube (*st*, B), towards *d*, where, by independent perforations, they enter the main duct, which at this point raises itself into a sort of papilla, having a sieve-like end. In the red ant, a similar gland (K, Plate VII.) has its cells free, the propria being wanting. Its form as given should be studied. Tracing this duct onwards towards the mouth, we find it enter a pouch, or ampulla, lying at the side of, and beneath, a plate which forms what may be termed the mouth-floor (Fig. 17). The part (*pl*) of this plate drops as a flap towards, and joins, the upper extension of the tongue, so that food passing over the latter can be uninter-

ruptedly carried back, over the hypo-pharyngeal plate, to the œsophagus, or swallow beyond. Extremely strong and dark-coloured horn-like forms run backwards, and converge on each side, while near their ends are seen prominences which give attachment to the protractor pharyngis muscle (*pp*), which, by shortening, throws forward the whole arrangement, bringing the front of the plate close up

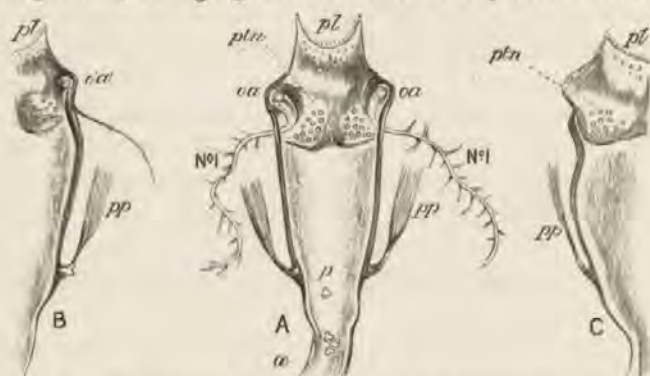


FIG. 17.—HYPO-PHARYNGEAL PLATE (Magnified Twenty-five times).

A, Plate in Worker—*pl*, Plate Leaflet; *No. 1*, Main Duct of System No. 1, with Acini removed; *ptn*, Papillæ of Taste Nerve; *oa*, Opening of Ampulla for Escape of Secretion; *pp*, Protractor Pharyngis Muscle; *p*, Pollen Grains in Commencement of (Esophagus). B and C, Halves of Pharyngeal Plate from Queen and Drone (lettering as before.)

behind the epipharynx (*g*, Plate II.). We find what at first might be taken for apertures at *tn*, but a careful examination shows these to be delicate papillæ of the taste nerve, which runs beneath the pharynx, and passes its terminating fibrils into them. But our main point now is the discharge opening (*oa*) of System No. 1, a portion of whose duct, with its continuation through the plate, is represented, though

deprived of its acini, which are broken away by the least violence.

Systems No. 2 and No. 3 are intercellular, like the spinning gland, whence they are derived—*i.e.*, the cells are arranged around a cavity, towards which they present their secreting surfaces, while they absorb material from the blood by that portion lying next the propria (*a*, C, Fig. 16). The secretion passes forwards in a manner made obvious by the illustration. When the several ducts begin to unite, they develop an interior spiral thread like to that of the tracheæ, both in purpose (page 34) and appearance. Their presence led Fischer to suppose these glands to be lungs. In System No. 3 these threads are especially strong, as indicated at *a* A, *d* D. They pour their contents into a sac (*sc*, A), curiously covered by star-shaped plates. The ducts of both systems uniting, as previously described, form a single channel, passing onwards through the mentum (*mt*, Fig. 18), or chin, into the tongue, where it terminates in a salivary valve (*sv*, A, Fig. 18), from which the saliva is pumped out during the action of sucking, an operation which may be artificially performed after the death of the bee.

System No. 4 of Schiemenz, or the olfactory gland (*Riechschleimdrüse*) of Wolff* (*og*, Fig. 10), closely resembles No. 1 in its minute structure, being intracellular, and, in consequence, very active. It has its aperture immediately within the mandible, is singularly large in the queen, smaller in the worker, and still less in the drone.

* "Nova Acta Acedemia Naturæ Curiosorum," vol. xxxviii., "Das Riechorgan der Biene," Dr. O. J. B. Wolff.

A question of surpassing interest, but immense difficulty, now presents itself, viz., What is the purpose served by each of these glands? Admitting, for argument's sake, that the view taken in the last chapter, of the office of the stomach-mouth, is correct, we have three or four distinct functions to be performed by such structures as we are now considering. First, a secretion to assist digestion; second, to change the cane sugar of the nectar of flowers into the grape sugar of honey, and possibly also convert starch into sugar (both of these functions are performed by one salivary secretion in our own case); third, to soften and make plastic the wax plates formed on the under side of the abdomen, so that they may be elaborated into comb, and also possibly serve as a vehicle in the moulding of propolis, or the application of it as a varnish; and, fourth, the production of a brood food.

Without dogmatising, my investigations into this question lead me somewhat confidently to point to System No. 1 as actually having the latter office. For it is first worthy of remark, that this gland—the largest and most active—is only found in the worker bees. By referring to Fig. 17, we note that B, the hypo-pharyngeal plate of the hive queen, has scarcely any perforation, and that the merest trace of duct is attached to it, having clearly no secreting power. It is peculiarly important, as well as interesting, to observe here, in a parenthesis, that, the higher the quality of the queen, the further will she be removed from the worker in this matter, poor queens, hurriedly raised, really possessing this gland in an extremely rudimentary form, while those

with the largest ovaries have even the plate imperforate, while no trace of duct is discoverable, just as in the case of the drone plate (C). But taking a queen *Bombus* (page 13), engaged in establishing a nest, when she does feed her own brood, we find this particular gland strongly developed; whilst in other bees, such as the mother *Megachile centuncularis* (page 9), which secretes no wax, but raises her own young, we still see it, though of smaller form. We thus get some evidence that rendering wax plastic is not the duty of this gland, but that the feeding of brood is. Again, examining a young worker employed in nursing, we find this gland turgid, and in the highest state of activity; while in the old bees of a broodless stock it is much shrunken, at the same time that glands No. 2 and No. 4 retain their normal size. Coupling this fact with the larger dimensions of No. 2* and No. 4 in the queen, and remembering her need of assimilation in order that her eggs may be produced, we shall not be far wrong in ascribing to No. 2 and No. 4 a digestive function. In other words, they are truly salivary in character, which position is further supported by the existence of these glands in less development in the drone. But to return; microscopical examination of the food given to *very young* larvæ reveals no trace of a pollen grain, and shows that it resembles in nothing any part of the contents of the chyle stomach of the nurses. It is, on the contrary, just such a fluid as a

* Siehold, followed by Girard, says that No. 2 is small in the queen; but this is clearly an error. In many scores of queens dissected, I have uniformly found it larger than in the worker, and often containing sacules.

secretion might be. As, however, the larva gains size and power, the process of weaning commences, and its food undergoes a change, having now undoubted pollen, honey, and water added to it—the glandular secretion being, of course, gradually withdrawn. The pollen grains, moreover, are living, and are generally found in a growing condition, proving that they have never entered the stomach of the nurse, and, certainly, that they are not semi-digested, and so utterly contradicting the Dufour theory. In the case of the queen larva, I discover that weaning is not adopted, but that secretion, commonly, though, as I hold, erroneously, called royal jelly, is added unstintingly to the end; so that, at the close of the feeding period, an abundance of highly nutritious food, which I apprehend does not intrinsically differ from that at first given to the worker larva, remains, and to which the chrysalis for some time adheres, possibly continuing to draw from it, by osmose (fluid diffusion), material which aids its development. The queen larva does get a very small addition of pollen, the residue of which collects in the middle bowel; but this seems to be rather accidental than otherwise.

The first brood food, or pap (page 19)—I am almost tempted to say bee milk—is, then, a highly nitrogenous tissue-former, derived from pollen by digestion, and has, apparently, a singular power in developing the generative faculty; for I find drone larvæ receive much more of it than those of workers, to whom any accidental excess possibly gives the power of ovipositing, as we find it in the abnormal fertile worker. From these considerations, I have been led towards a theory, the

evidence in favour of which has accumulated until I cannot but regard it as established. It is, that the queen, if not always, at least during the time of egg-laying, is fed by the workers from the secretion of gland No. 1, with possible additions from some of the others.

It has been already stated (page 26), that the queen, at certain periods, has the power of producing between 2,000 and 3,000 eggs daily. Each one of these is $\frac{1}{14}$ in. long, $\frac{1}{10}$ in. in diameter; and a careful calculation shows that 90,000 would occupy a cubic inch, and weigh 270 grains. So that a good queen, for days, or even weeks, in succession, would deposit, every twenty-four hours, between six and nine grains of highly developed and extremely rich tissue-forming matter. Taking the lowest estimate, she then yields the incredible quantity of twice* her own weight daily, or, more accurately, four times, since at this period more than half her weight consists of eggs. Is not the reader ready to exclaim, What enormous powers of digestion she must possess, and, since pollen is the only tissue-forming food of bees, what pellets of this she must constantly keep swallowing, and how large must be the amount of her dejections! But what are the facts? Dissection reveals that her chyle stomach is smaller than that of the worker, and that, at the time of her highest efforts, often scarcely a pollen grain is discoverable within it, its contents consisting of a transparent mass, micro-

* Queens vary considerably in weight, small ones, in the winter, not exceeding $1\frac{1}{2}$ grains, while a few, in the middle of the spring-laying, will turn the scale at 3 grains—feeding adding fully half a grain more.

scopically indistinguishable from the so-called royal jelly; while the most practised bee-men say they never saw the queen pass any dejections at all. These contradictions are utterly inexplicable, except upon the theory I propound and advocate. She does pass dejections, for I have witnessed the fact; but these are extremely watery, and are voided with great energy, while she rests, back downwards, on the bottom of the comb. At least, this has been her position when I have noted the occurrence. Moreover, although her stomach is small, her urinary tubes are exceedingly active and large, adding further confirmation to my position, as these enable her to rid herself of the great excess of water a secretion diet would supply. We thus see that her digestive function is performed by proxy, the residuary matter of the pollen required to produce her eggs being, under this exceedingly beautiful arrangement, carried from the hive in the bodies of the feeding bees, to be expelled in mid-air—so wondrous are the devices by which the requirements of these creatures are met.

When first hatched, the queen is not noticed—she is but one of the multitude, requiring nothing special, and has, of course, no feeding attendants, but takes her nourishment from the cells, like the rest, and empties her bowels when on the wing, like a worker. Her weight does not at this time increase, or she would become incapable of all the soaring of the marital trip. Now her stomach always contains pollen; but, from the hour of her impregnation, she is the subject of watchful attention, the younger bees gathering about her, not to form her body-guard, as writers

have generally fancied, but to minister to her necessities; and her weight from this time rises very rapidly, her ovaries developing under the influence of what I shall call chyle* food, which, two or three days after impregnation, her stomach contains in quantity, while all trace of pollen has disappeared; but if I be not correct, this is the period above all others when large quantities of pollen should be undergoing digestion. I have sacrificed many queens just when at their very highest value, for the purpose of settling, as far as may be, this important inquiry, with results most uniform and confirmatory. Here, too, I imagine we get the key to the retarded laying, always noticed when a queen fails in impregnation; it is because the bees themselves fail in administering that kind of nourishment which stimulates the ovaries. And, in addition, we learn how it is that the colony have under control the laying powers of their queen, stimulating her or not, as circumstances warrant.

It is necessary now to observe that honey, like sugar, is what the physiologist denominates a "force-former," and, as such, is needed by the queen to supply her activities, and so queens may be seen to dip their heads into honey cells and there drink; while a queen not laying may be supported for some time upon sugar syrup alone.

The ducts of Systems No. 2 and No. 3 are so placed

* System No. 1 Siebold has unfortunately called "salivary," in ignorance of the facts to which I now call attention. Since this term is very misleading, I shall refer to this gland hereafter as the chyle gland.

that their secretions are given up only as the tongue is *protracted* or extended as for sucking (see Figs. 18 and 19), while the peculiarity of the position of the discharge opening of the chyle gland (No. 1) is just such as my theory requires. There exists upon the worker's tongue, and upon the worker's only (Plate II., and *gr* B, Plate III.), a feeding-groove, or narrow trough, on to which honey is brought by the compression of the honey-sac when one bee feeds another. Just at the back of this feeding-groove, when the tongue is retracted (see A, Fig. 19), lies the plate into which the chyle gland (No. 1) opens; and, by a combination of most extraordinarily complicated muscles, between thirty and forty in number, the chyle can then be taken from this feeding-gland, and placed upon the groove at once, for the benefit of the queen; or it can also, when the tongue is doubled back in repose, be brought into the right position for feeding the larvæ from the mouth, as the latter lie at the bottom of the cells. There are yet other considerations pointing in the same direction, which must not be anticipated until we come to practical matters.

Since I am not conscious of a single fact which appears in any way to throw doubt upon what I have advanced, while every point examined has brought to it additional corroboration, I leave the argument to speak for itself, lest this chapter become unduly lengthened. Every advanced bee-keeper will see its practical importance, and that it dispels the shades of many mysteries; while the naturalist will, in delight, realize that his bee is more a wonder of wonders than he has before imagined.

CHAPTER VII.

TONGUE AND MOUTH PARTS.

Endo-Skeleton of Thorax and Head—Meso-cephalic Pillars—Mouth of Bees—Mandibulæ, Labrum, and Labium—Mentum not Tubular—Labial Palpi and Maxillæ—How Large Quantities of Honey are Taken—One Use of the Epipharynx—The True Sucking Tube of Bees—Sucking Small Quantities of Nectar—Sheath—Rod—Centre and Side Ducts of Tongue—Bouton—Pouch—Solidity of Tongue: How Simply Determined—Necessity of Pseudo-Tubular Form—How to Distend Pouch Artificially—Queen and Drone Tongue—How Tongue is Folded out of View—Folding by the Andrenidæ—Nectar Converted into Honey—Why Bees Take Thick Syrup Slowly—Feeding Brood in Cells—Reasons for Wedge Shape of Head.

AS we now commence another section of our anatomical studies, leaving the internal organs for those that, in large part, appear at the surface, some introductory remarks are necessary.

The skeleton of insects, although external, is not exclusively so—*e.g.*, in the thorax of bees, subject as

it is to the strain of the leg and wing movements, corrugations and plaitings, supplemented by internal webs (*see* Plate I.), are provided, to give the needed rigidity, just as the engineer secures the same by corrugating his sheet iron, and adding webs to his girders. Beside these, between the meso and meta-thorax, lies a stiff extension—really a plate bone—called the meso-phragma, to give solid attachment to part of the muscles of the organs of flight.

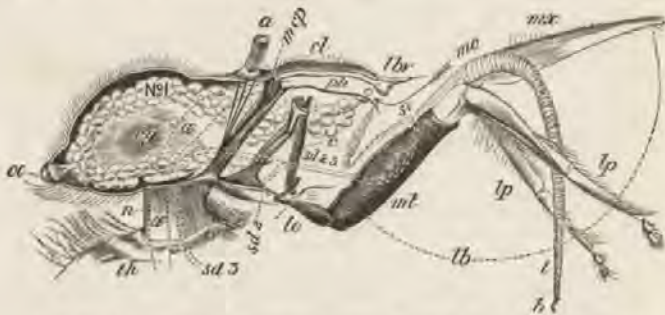


FIG. 18.—LONGITUDINAL SECTION THROUGH HEAD, JUST OUTSIDE RIGHT ANTENNA (Magnified Fourteen times).

a, Antenna, with Three Muscles attached to *mcp*, Meso-cephalic Pillar; *cl*, Clypeus; *lbr*, Labrum, or Upper Lip; No. 1, Chyle Gland (System No. 1 of Siebold); this Gland really runs in front of the Meso-cephalic Pillars, but here the latter are kept in view; *a*, Opening of same; *oc*, Ocellus, or Simple Eye; *cg*, Cephalic Ganglion; *n*, Neck; *th*, Thorax; *es*, Esophagus; *sd 2, 3*, Common Salivary Ducts of Systems No. 2 and No. 3; *sd 2* and *sd 3*, Salivary Ducts of Systems No. 2 and No. 3 respectively; *sv*, Salivary Valve; *c*, Cardo; *ph*, Pharynx; *lb*, Labium, or Lower Lip, with its Parts Separated for Display; *mt*, Mentum, or Chin; *mx*, Maxilla; *lp*, *lp*, Labial Palpi; *l*, Ligula; *b*, Bouton.

In the head, which has to sustain the heavy pull of the jaw and tongue muscles, besides defending the brain and delicate glands, corrugation is prevented by the presence of the very large compound eyes, with their essential regularity of outline, an element of weakness, unless some device were introduced to

Apiary," derives his chief facts; but, unfortunately, he has added to these several statements which are astoundingly inaccurate, and from which our minds must be freed at once, if we are to have any intelligent idea at all of the tongue of the bee. Since his book has been largely read in this country, and its teaching generally accepted as the result of those microscopic examinations of which it continually speaks, I must refer to these and other errors, in the interest of naturalists and bee-keepers, as we progress; and, happily, they are not those which, on account of their difficulty, leave room for diversity of opinion, but such as can easily be made clear, even, in some cases, without a microscope.

The mouths of all insects have the jaws moving sideways. The caterpillar, which carves our cabbage-leaves with an industry which cannot secure our approval, places itself at the edge of the leaf, driving one jaw through the upper, the other through the lower surface thereof. In like manner, our bee has its mandibulæ, or outer jaws (*m*, Plate II.) at the right and left of the upper lip, or labrum, which depends between, and is provided with a row of delicate feeling hairs. These jaws are notched, in the queen and drone (Plate IV.), as we find them in wild bees, but are entire (*i.e.*, not notched) in the worker (Plate II.), are very powerful, and serve, amidst many purposes, to be noticed in due course, for biting, as well as thinning out wax shreds in comb building. Beneath the upper lip appears (at *g*) the front of the epipharynx, covered by a delicate white membrane, and containing an abundance of nerves, endowing it with

some special sense, which Wolff concludes to be smell—an opinion in which I cannot agree, for reasons given hereafter. The under side of the mouth-opening (*mo*, Fig. 18) is formed by the labium, or under lip (*lb*), which is seen to embrace a number of parts, carried by its basal portion, or mentum (*mt*, Fig. 18, or B, Plate III.). The mentum lies beneath the head, and somewhat behind it, and can, within considerable limits, be moved backwards and forwards. It is strongly chitinous below, is articulated to the head by means of the sub-mentum, or lora (*lo*, Fig. 18, or I, B, Plate III.), and contains the muscles (*a, a, rb*, B, Plate III.), which can draw the tongue, or ligula, partly back into it, and also conveys the salivary duct (*sd*, Fig. 18), which opens by a valve (*sv*) at the base of the ligula. Otherwise the mentum has no opening, is filled with blood, has nothing to do with the œsophagus, or swallow, and is, of course, *not* tubular, as Cook states. The ligula is not a continuation of the mentum in front, but has its roots *within* the latter, from which it is withdrawn by the action of a muscle (the *protractor linguæ*), when the tongue is outstretched for sucking. Attached to the mentum at its front margin, and possessing at this point a hinge joint, we have on each side of the ligula a labial palpus (*lp*, Fig. 18 and Plate II.). It consists of four joints, the two upper being large, the two lower very small, and provided with elaborately contrived feeling hairs. Outside these we find the maxillæ (*mx*, Fig. 18, and Plates II. and III.), attached to the sub-mentum (the right maxilla has been removed in Fig. 18), and having a chitinous portion

hollowed out, and fitting against the side of the mentum, which it partially embraces with very stiff hairs, so that they hold it in position. The maxillæ have feelers or palpi (*mxp*, Plate II.), which appear in the hive bee to be aborted and functionless, although in the *Andrenidæ* they are usually well-developed. Not far below the feeler, the maxilla, like the labial palpus, has a hinge, separating the higher, tougher part (the stipe) from the lower, more delicate, and transparent portion forming the lacinia, or blade. The sections C, D, E (Plate III.) show that the maxillæ and labial palpi normally embrace the tongue before and behind respectively, so that together they may form a tube, within which the tongue is placed. If we now remember that the tongue can be drawn back in part into the mentum, while the embracing parts cannot, we see at once that the tongue has the ability to move up and down within the formed tube; and again, that as the maxillæ are attached to the lora, the maxillæ may move backwards and forwards upon the labial palpi.

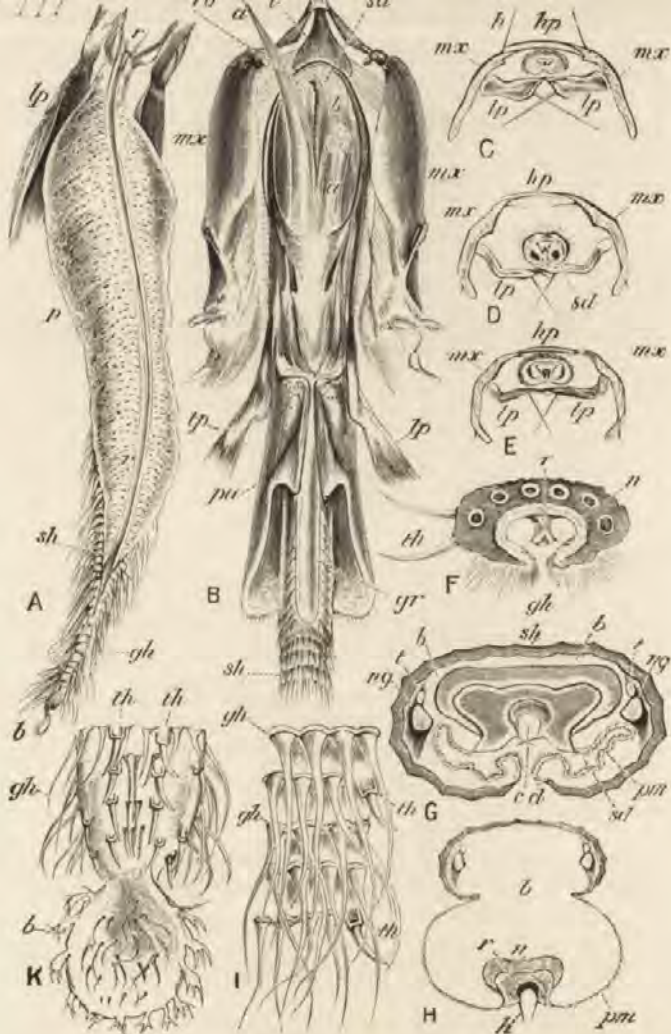
With the outline before us of the main parts of this complex structure, let us endeavour to understand the methods of its action, and the purposes to which it has been adapted. First, How are large quantities of honey taken? The ligula, when examined by a low power, is found to be covered by a sheath (*sh*, B and G, Plate III.), densely clothed with hairs, regularly arranged, in the worker, in from 90 to 100 transverse rows, of which the queen and drone only possess from sixty to sixty-five. These hairs, most symmetrically placed, and passing through

a beautiful gradation of form, from row to row, are short and triangular in shape near the base of the organ, long and spiny about the middle, smaller and more flexible near the apex, while amongst them are found hairs with a bulbous structure, provided with a nerve which constitutes them touch organs, or true tactile hairs (*th*, I, Plate III.). The high elasticity of the ligula, depending upon the structure of a rod running through its centre, allows it to be used as a lapping tongue when any considerable quantities of syrupy food are at command. As it then sweeps backwards and forwards, the front side turned down, the gathering hairs (*gh*, Plate III.) get loaded, while the labial palpi and maxillæ are so placed round it as to form a perfectly airtight tube. C, D, E, Plate III., show the palpi with the hairs crossed behind, while the hyaline plates (*hp*, C) of the two maxillæ lie over one another. Each maxilla is beautifully furnished with a line of hairs (*h*) in front of it, and a groove at its back; both of these act as mechanical stops, and accurately adjust the position of the two maxillæ, preventing them, as they are drawn together by their proper muscles, from approaching too nearly whichever plate may happen to take the front position. But although the tube so made up is airtight, it cannot act as a suction pipe, because it is open above, as may be seen by reference to Plate II. But now the front extension of the epipharynx (*g*) closes down to the maxillæ, fitting exactly into the space they leave uncovered, and thus the tube is completed from their termination to the œsophagus.

An important question now arises: How is this act of sucking performed? Some have supposed that the suction originated in the mouth; while Cook calls the honey-sac the "sucking stomach," using an old, but extremely misleading, title, for this wrinkled membrane could no more exert suction than could a balloon extract gas from the main. Comparing D with E, Plate III., which are cross sections at the *same* point, we see that the space (through which the nectar must travel) surrounding the ligula, and between the palpi and maxillæ, is three times as great in the former as the latter. This greater space is obtained by arching the maxillæ above the ligula, and so causing the former to retreat from the palpi. Here, then, is the origin of the sucking. The tube is made to expand rhythmically above, the nectar follows up into the space thus provided, and then, as this contracts again, travels on into the pharynx, as B, Fig. 19, will make clear.

Second, How is nectar taken when smaller quantities only are obtainable? A more minute investigation of the ligula is now essential.

The so-called sheath of the tongue is highly chitinised, stout, and very elastic, while the hairs which clothe it are broad at their bases (*gh*, I, Plate III.), and pre-eminently suited to gather up syrupy fluids by capillarity, but utterly unfit for collecting minute quantities of nectar, only reachable, perhaps, by the extremity of the tongue, as would be the case in most flowers, especially those with a tubular corolla. Here, then, another and surprisingly beautiful contrivance meets us. Taking a cross section through



DETAILS OF TONGUE STRUCTURES OF BEE.

A, Under Side of Ligula—*lp*, Labial Palpus; *r, r*, Rod; *p*, Punch; *sh*, Sheath; *gh*, Gathering Hairs; *b*, Bouton, or Spoon. B, Underlip or Labium, with Appendages, partly dissected—*l*, Lora or Submentum; *a, a*, Retractor Linguae Longus *sd*, Salivary Duct; *rb* and *b*, Retractor Linguae Biceps; *mx, mx*, Maxilla; *lp, lp*, Labial Palpi; *pa*, Paraglossa; *gr*, Feeding Groove; *sh*, Sheath of Ligula. C, D, and E, Cross Sections of Ligula—*hp*, Hyaline Plate of Maxilla; *h*, Hairs acting as Stops; *mx*, Maxilla; *lp*, Labial Palpi; *sd*, Side Duct. F, Cross Section of Extremity of Tongue, near Spoon—*th*, Tactile Hairs; *r*, Rod; *n*, Nucleus; *gh*, Gathering Hairs. G, Cross Section of Tongue without Gathering Hairs, magnified 400 times—*sh*, Sheath; *b*, Blood Space; *t*, Trachea; *ng*, Gustatory Nerve; *cd*, Central Duct; *sd*, Side Duct; *pm*, Plaited Membrane. H, same as G, but magnified 200 times, and with *pm*, Plaited Membrane, turned outwards, as in A.—*b*, Blood; *n*, Nucleus; *r*, Rod; *h*, Closing Hairs. I, Small Portion of Sheath—*gh*, Gathering Hairs; *th*, Tactile Hairs. K, Extremity of Tongue, with Spoon, lettering as before; *b*, Branching Hairs for Gathering.

the middle of tongue (G, Plate III.), we note, first, that the strong sheath, *sh* (from which the gathering hairs have been removed, for the sake of clearness), passes round the tongue to the back, where its edges do not meet, but are continuous with a very thin plaited membrane (*pm*), covered with minute hairs. This membrane, after passing towards the sides of the tongue, returns to the angle of the nucleus, or rod, over the under surface of which it is probably continued. The rod passes through the tongue from end to end, gradually tapering towards its extremity, and is best studied in the queen, where I trace many nerve threads and cells. It is undoubtedly endued with voluntary movement, and must be partly muscular, although I have failed completely in getting any evidence of striation. The rod on the under side has a gutter, or trough-like hollow (*cd*, the central duct), which is formed into a pseudo-tube (false tube) by intercrossing of back hairs. It will also be seen that, by the posterior meeting of the sheath, the space between the folded membrane (*sd*) becomes two pseudo-tubes of larger size, which I shall call the side ducts.

These central and side ducts run down to that part of the tongue where the spoon, or bouton (*b*, Plate II.; K, Plate III.), is placed. This is provided with very delicate split hairs (E, Fig. 24), capable of brushing up the most minute quantity of nectar, which, by capillarity, is at once transferred by the gathering hairs (which are here numerous, long, and thin) to two side groove-like forms at the back of the bouton, and which are really the opened out

extremity of the centre and side ducts, assuming, immediately above the bouton, the form seen in F, Plate III. The central duct, which is only from $\frac{1}{800}$ in. to $\frac{1}{1000}$ in. in diameter, because of its smaller size, and so greater capillary attraction, receives the nectar, if insufficient in quantity to fill the side ducts. But good honey-yielding plants would bring both centre and side ducts into requisition. The nectar is sucked up until it reaches the paraglossæ (*pa*, B, Plate III.), which are plate-like in front, but membranous extensions, like small aprons, behind; and by these the nectar reaches the front of the tongue, to be swallowed as before described. Thus, then, the bee is equipped to take advantage of all sources of supply. She can gulp down big draughts, or sip a stream of nectar so fine that 600 miles of it will, when evaporated, store but a 1lb. section box.

We are now, then, in a position to settle the question that has disturbed the minds of entomological and apicultural writers for the two centuries and more elapsing since the time of Swammerdam—Is the bee's tongue solid, or is it tubular? The problem has been one of the highest difficulty to the microscope, depending upon the determination of the nature of the back of the central duct, and authorities have been pretty equally balanced respecting it. I agreed entirely with Wolff, that the duct was a trough, and not a tube; but this left the question one of authority or observation, and so still open to debate. But, luckily, a form of experiment occurred to me which settles the dispute most conclusively, and in such a way that a 10s. microscope will answer

as well as a better one. Bees have the power, by driving blood into the tongue, of forcing the rod out from the sheath, and distending the wrinkled membrane, so that in section it appears as at H, Plate III., the membrane assuming the form of a pouch, given in full-length at A. It will be seen at once that this disposition of parts abolishes the side ducts, but brings the central duct to the external surface. The object of this curious capability on the part of the bee is, in my opinion, to permit of cleaning away any pollen grains, or other impediment that may collect in the side ducts. The membrane is greasy in nature, and substances or fluids can be removed from it as easily as water from polished metal. If, now, the side of a needle, previously dipped into clove oil in which rosanilin (magenta) has been dissolved, so as to stain it strongly red, be touched on the centre of the rod, the oil immediately enters, and passes rapidly upwards and downwards, filling the trough. I could not resist laughing, while my pulse certainly went faster, as I realised the absurdly simple means which put that matter within the grasp of the tyro, with his simple lens, which had kept many learned doctors wrangling, notwithstanding all their appliances. It is a pseudo-tube, then, and nothing more. Hairs cover it, and these permit of its being entered by the side.

The impossibility of cleaning, and so the tremendous risk, or, rather, the certainty, of clogging, which a closed tube would involve, does not appear to have disquieted those who have been wrongfully describing the bee's tongue as tubular; but there is yet another consideration, which should show us the

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surpassingly beautiful suitability of the form now explained, for, although a tube would be fatal, a tubular form is essential, as we shall presently see. Large quantities of nectar *may* safely enough be gathered *outside* the ligula in contact with the air, but small quantities so collected would, in warm and dry weather, inevitably thicken into a glue, which would at once fix the poor little tongue, and for the time, if not altogether, stop its labours. Sparing supplies are, therefore, made to pass through the centre and side ducts. The former is doubly protected from evaporation, and by its channel the tiniest stream would be as limpid at the mouth as when it left the bouton; while the side ducts, although more exposed, only permit of such inconsiderable evaporation that no risk whatever exists, while the pollen grains that may perchance enter can be cleaned from it in the manner we have already seen.

Cook says the sac to which we just now directed our attention "may be distended with *nectar*, as it has connection with the *tube* of the mentum"—statements utterly at variance with the anatomy of the parts, and capable of complete refutation by a very elementary experiment. If hatching brood be removed from the hive to a position too dry or too cool, some of the bees will only succeed in freeing their heads from the cells, and will, in this position, die. Of course, they have not fed, and yet in the majority of cases the tongue pouch will be fully distended, because the enforced stillness of the body, and activity of the head, has determined an excess of *blood* into the latter. Many will like to repeat my

experiment upon the central duct, for which stained glycerine or honey may be used instead of oil, although the latter is to be preferred. Let me explain, then, how distended pouches may be obtained without sacrificing any brood. I reflected that blood might *artificially* be driven into the pouch; and, taking a recently dead worker, pinched the thorax between thumb and finger from behind forwards; instantly the pouch filled out, returning into position as the pressure was relaxed. In nine cases out of ten, this experiment with workers succeeds; with queens it is difficult, on account of the extreme hardness of the thoracic plates.

The queen's tongue is not only short, but the central and side ducts are not drawn out to the delicate terminations we find in the worker, exactly as we should have expected, since she has not to lap minute quantities of nectar from the bottoms of blossom cups, but simply to take food from cells, or, more commonly, from the tongues of her attendants. As is also clearly necessary, the feeling hairs in her case are far more developed than in that of the worker, enabling her to determine in the darkness of the hive the exact point of the feeding bee's body that she is approaching. The drone's tongue, in like manner, is short, but is not highly sensitive.

All observant bee-keepers must have noticed that the long and lithe tongue of their little assistants disappears in a most astonishing fashion when no longer required. Fig. 19 will make clear the method of its folding. At B we see it extended. It is retracted by partly withdrawing it into the mentum,

as before stated, and carrying the mentum itself backwards, by which movement the delicate skin lying between the two secretory openings bends upon itself, and the tongue, embraced by the maxillæ, doubles back behind the head, as at A. So that, in-

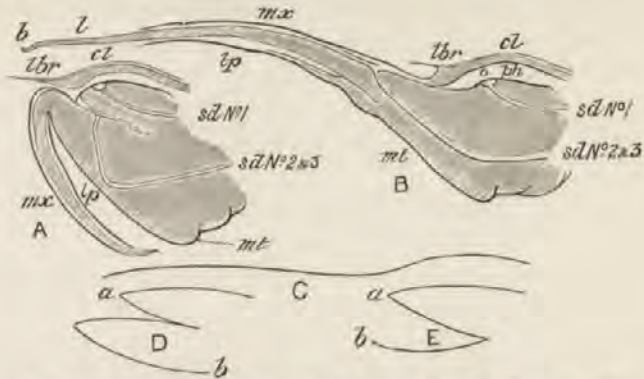


FIG. 19.—IDEAL SECTIONS THROUGH TONGUE (Magnified Twelve times).

- A, Tongue Fully Retracted. B, Tongue Outstretched for Sucking; lettering as Fig. 18. C, Ideal Line of Pharynx and Tongue in Activity. D, Method amongst the *Apidae*, or Long-Tongued Bees, of Folding Tongue in Repose—*a*, Articulation at Base; *b*, Bouton, or Point. E, Method amongst the *Andrenidæ*, or Short-Tongued Bees, of Folding Tongue in Repose; lettering as D.

stead of presenting one sweep line (C), it is divided into three between *a* and *b* (D). The whole family of the *Apidae* thus turn the point of the tongue backwards, while the *Andrenidæ* (see page 8) turn it forwards by a single doubling.

A most beautiful adaptation here becomes evident. Nectar gathered from blossoms needs conversion into honey. Its cane sugar* must be changed into grape sugar, and this is accomplished by the admixture of

* See "The Chemistry of the Hive," Otto Hehner, F.C.S., *British Bee Journal*, 15th Nov., 1883.

the salivary secretions of Systems No. 2 and No. 3, either one or both. The tongue is drawn into the mentum by the shortening of the retractor linguæ muscle, which, as it contracts, diminishes the space above the salivary valve, and so pumps out the saliva, which mixes with the nectar as it rises, by methods we now understand.

Bees, it has often been observed, feed on thick syrup slowly; the reason is simple. The thick syrup will not pass readily through minute passages without thinning by a fluid. This fluid is saliva, which is demanded in larger quantities than the poor bees can supply. They are able, however, to yield it in surprising volume, which also explains how it is that these little marvels can so well clean themselves from the sticky body honey. The saliva is to them both soap and water, and the tongue and surrounding parts, after any amount of daubing, will soon shine with the lustre of a mirror.

The tongue is kept fully drawn back during the feeding of brood, and the salivary valve is now not only closed, but shut completely out of action by the folded skin (A, Fig. 19); while the chyle gland (No. 1) is brought up close to the tongue root, and into the precise position for feeding from between the mandibles. The wedged shape the tongue and head take together is highly suggestive when the form of the cell at the bottom of which the larva lies is remembered. This wondrous tongue has no speech, but yet who so dull that cannot hear its thrilling little voice, speaking as unmistakably as the stars discourse the language of the immensities?

CHAPTER VIII.

ORGANS OF SPECIAL SENSE—ANTENNÆ AND EYES.

Difficulty of Subject—Touch, Taste, and Sight—Antennæ—Movements of Scape and Flagellum—Feeling Hairs—Smell Hollows—Special Formation in Queen—Conoid Hairs—Six Distinct Structures—Hearing Organs—Sir J. Lubbock's Experiments—Proofs of Bees Hearing—Smelling—Experiments with Male Moths—Comparison of the Sexes—Number of Smell Organs—The Equipment of the Drone—Compound Eye—Pigment—Hexagonal Facets—Methods of Examination—Crystalline Cone—Nerve Elements of Eye—Mosaic Vision—Microscopic Experiment—Stemmata—Colour Sense—Albino and Eyeless Drones—Eyes of the Sexes Compared—Conclusion.

THE study of the special senses of creatures so far removed from ourselves as bees cannot but present great difficulties, quite apart from the minuteness of the structures involved; for it is by no means impossible—nay, it is, rather, highly probable—they possess modifications of sensibility which we can no more truly realise than can the blind imagine the difference between red and green.

We have already seen that bees are not wanting in the sense of touch, although it does not reside in the exo-skeleton, but in multitudes of tactile hairs, distributed as required. The sense of taste, too, is possessed by the mouth and tongue, the hypo-pharyngeal plate in the first being pierced for nervous extensions (page 78), while the second has, on each side, at its root, thirty-two papillæ, which are entered by nerve end cells, just at the spot in which the nectar meets the salivary secretion. In addition, analogy seems to point to the nerve endings of the epipharynx as also being taste organs. As the use of the eye is obvious enough—upon the supposition that bees may enjoy the senses common to animals higher in the scale of creation—we have yet to look for organs of hearing and smelling, and it will be well for us to bear this in mind as we investigate the antennæ, commencing with those of the worker.

These cylindrical organs (*a*, Plate II.) are inserted near to each other, just above the margin of the clypeus, and consist of two main portions—a single long joint, denominated the scape, and eleven succeeding short joints, called the flagellum. By a hemispherical cup, the scape is articulated to the cranium, the latter being moulded into a concavity (shown by shading in the Plate), to permit of the widest range of motion on the part of the former. The movements of the scape are controlled by three muscles, seen lying behind the antenna root (Fig. 18). One throws it outwards, the second raises and draws inwards, the third depresses. Two muscles in the scape itself (*lm*, *dm*, Fig. 20) move the flagellum. The second, third, and fourth

joints are well clothed with hairs, but otherwise are dissimilar to one another, and to the remaining eight, these last having a common structure of a highly complicated character. The joints are not telescopic, but are articulated (as at B, Fig. 20), with a central opening between each, whose width is rather less than half of their total diameter. They have only

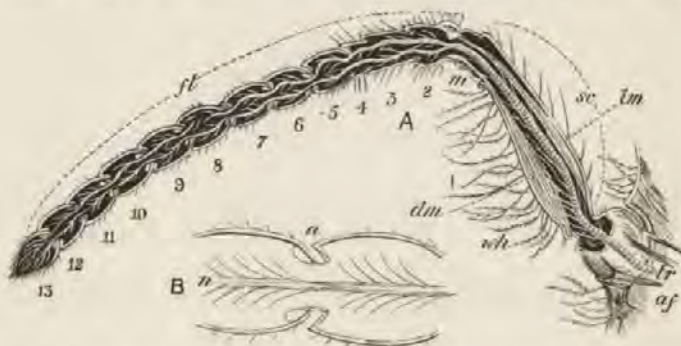


FIG. 20.—LONGITUDINAL SECTION OF DRONE ANTENNA, Nerve Structures removed (Magnified Twenty times).

sc, Scape; *fl*, Flagellum; 1, 2, 3, &c., No. of Joints; *af*, Antennary Fossa, or Hollow; *tr*, Trachea; *m*, Soft Membrane; *wh*, Webbed Hairs; *lm*, Levator Muscle; *dm*, Depressor Muscle. B, Small Portion of Flagellum (Magnified Sixty times)—*n*, Nerve; *a*, Articulation, or Joint.

very slight relative movement, and this is brought about by contractile connections (*a*, B). If the eight joints referred to be examined by the microscope, it will be seen at once that the front and back faces are totally unlike. The back is sparsely covered by regularly placed hairs, somewhat curved, and pointing downwards, whilst here and there hairs larger and quite straight are seen (*c*, B, Fig. 22). The front is similarly furnished, but the spaces between the hairs are here filled with oval discs, depressed in the

centre, and having two or three faintly visible concentric rings. These structures, although the first to strike the eye, are the most difficult to understand, and so had better be considered last.

Schiemenz* has examined the antenna by sections, and since my own work shows me the accuracy, beauty, and success of his, I adopt his drawing (Fig. 21), with only one or two modifications. The smaller hairs (*f, f*) are loosely set into the chitine framework of the antenna by a delicate ring, into which rises a nerve end cell with a distinct nucleus. These hairs, standing above the general surface, constitute the antennæ marvellous touch organs; and, as they are distributed all round each joint, the worker bee in a blossom cup, or with its head thrust into a cell in the darkness of the hive, is, by their means, as able accurately to determine as though she saw; while the queen, whose antenna is made after the same model, can perfectly distinguish the condition of every part of the cell into which her head may be thrust. The last joint, which is flattened on one side, near the end, is more thickly studded, and here the hairs are uniformly bent towards the axis of the whole organ. No one could have watched bees without discovering that, by the antennæ, intercommunication is accomplished; but for this purpose front and side hairs alone are required; and the drone, unlike the queen and worker, very suggestively, has no others, since the condition of the cells is no part of his care, if only the larder be well furnished. The

* See Footnote, page 67.

conoid hairs (c' , Fig. 21) are probably only highly specialised feeling bristles, and are found in greatest number at the extremity of the antennæ. Each antenna carries no less than six distinct structures, viz., two forms of hairs not sensory on the scape and upper joints, the ordinary sensory hair, the conoid bristle, the elliptic discs, and, lastly, another structure about to be described, and which is extremely likely



FIG. 21.—LONGITUDINAL SECTION THROUGH PORTION OF FLAGELLUM OF ANTENNA OF WORKER (Magnified 300 times).

f, Feeling Hair; *s*, Stinging Organ; *ho*, Hollow; *c*, Conoid Hair; *hl*, Hypodermal Layer; *n, n*, Nerves, in Bundles; *ar*, Articulation; *c'*, Conoid Hair (Magnified 300 times).

to escape attention. Its external appearance is given (*ho*, B, Fig. 22), and consists, superficially, of minute holes, from $\frac{1}{8000}$ in. to $\frac{1}{12000}$ in. across, each surrounded by a bright reddish ring. The microscopist had better choose the antenna of a young drone, and use a $\frac{1}{2}$ in. or $\frac{1}{8}$ in. objective, with a Lieberkühn, and then—unless as patient as microscopists proverbially are—he will be as likely to lose his temper as find the object. It is situated at the lower part and outer side of the last six or seven joints of the flagellum, but is found in greater abundance as we get towards the end, the terminal joint carrying a

patch of perhaps twenty, which creep round towards the front. We have two of these in section (*ho*, Fig. 21), where we see the hole leads into a large cavity, beyond which extends a widening cone. I am not convinced that this cone is filled, as Schiemenz supposes, for I regard it as an organ of hearing, its larger size in the drone, with his possible need of distinguishing the sound of the queen's wings, and its position on the *outer* sides and ends of the antennæ, seeming to me to favour this opinion. It also appears to answer to parts considered to be auditory organs in other insects.*

Sir J. Lubbock has commonly been regarded as asserting the total deafness of bees; but, in a correspondence of some years since, the distinguished investigator assured me his position was negative, as he merely failed to get evidence of bees hearing. Sir J. Lubbock's experiments I cannot but regard as most inconclusive, since tuning-forks, whistles, and violins, emit no sounds to which any instinct of these creatures could respond. Should some alien being watch humanity during a thunderstorm, he might quite similarly decide that thunder was to us inaudible. Clap might follow clap without securing any external sign of recognition; yet let a little child with tiny voice but shriek for help, and all would at once be awakened to activity. So with the bee: sounds appealing to its instincts meet with immediate response, while others evoke no wasted emotion. In practical matters, the hearing of bees is not only often obvious, but must

* "Ants, Wasps, and Bees," page 227, Sir J. Lubbock (International Science Series).

be taken into account—*e.g.*, when a swarm is about to be transferred to its permanent abode from its temporary one, many will stick to the sides of the latter, after the bulk have been thrown out, and these, by their buzz, will distract those that are running in at the new hive door. The removal of the stragglers to a distance will end the disturbance, which will be renewed if they be returned to their former position. Some years since I was present in a tent where an expert had driven (*see* "Driving") five or six stocks, and nearly a pint of lost bees had collected for mutual comfort on a piece of damp canvas, at the bottom of the tent pole, against which the last skep was made to lean, as it was stood, quite late in the evening, on a table for operation. No sooner did the bees in this skep set up the well-known roar, than those on the canvas, so still hitherto, faced upwards, unhesitatingly ascending the pole, and settling on the outside of the roof of the receiving skep. This circumstance I remember as affording, to all who witnessed it, conclusive evidence of hearing.

In the progress of the present we moderns have, perhaps, too confidently condemned *all* the past. The conflict of the key and warming-pan of old swarming days has called forth some good-humoured, but possibly not always philosophical, banter, for I confess I think, that in its day, it had its value. Piping of queens, whatever be its cause, seems to point to a sense of hearing, for it appears to be a sound made for an object, and not the result of some necessary movement. Whether the organs we have just considered be those of hearing or not, the possession

of this sense by bees, of which much evidence will subsequently come before us, cannot be doubted.

We have now to consider the "smell hollows" (in cross section, *s*, Fig. 21), covered by a thin layer lying over a goblet-formed cavity beneath, into which passes a nerve end cell, clearly unlike that provided to the feeling hair (*f*). These oval forms are distinctly not tactile, on account of their depressed position, but, for reasons now following, almost certainly olfactory. That the sense of smell is possessed by the antennæ simple observations would appear to favour. If bees have food presented to them, the ends of the antennæ are, in alternation, brought close to it before the tongue is advanced. If it contains even a small quantity of an objectionable body which evaporates, the bee immediately retreats; but if the added substance be non-vaporisable, such as corrosive sublimate, the antennæ, although used, do not detect its presence. The tongue, however, immediately suffers, of which evidence is given by the hurried departure, and the earnest efforts made to clean away the cause of offence.

About three years since, near Bagshot, I carried across a heathy plain, skirted on each side by firs, a fresh female Emperor moth, lying at the bottom of a muslin bag. After travelling about a mile, I retraced my steps; and although, during several days' hunting for wild bees in the same locality, I had not seen an "Emperor," the males now met me, constantly flying fearlessly up to the muslin bag—my companion, a collector, having a very busy time. Similar facts every naturalist could relate. The antennæ of male moths are exceedingly large and extended in surface, and

the evidence that these are marvellously sensitive to some emanation from the female is universally accepted. But what of our bees? Let us compare the antennæ of the sexes. The flagellum, which is the sensory part of the antenna, I find, by careful measurement of many individuals, to be, on an average, in the queen, $\frac{1}{128}$ in. in diameter, $\frac{1}{11}$ in. long; worker, $\frac{1}{110}$ in. diameter, $\frac{1}{9}$ in. long; drone, $\frac{1}{82}$ in. diameter, $\frac{1}{8}$ in. long. So that the sensory surfaces in the three cases are very nearly in the ratio—queen 1, worker 2, drone 3. Yet the male, as his habits would lead us to suppose, has only about 2000 feeling hairs, being the one-sixth or one-eighth of the number of those possessed by the worker. But what of the smell hollows? In the case of the worker, the eight active joints have an average of fifteen rows of twenty smell hollows each, or 2400 on each antenna. The queen has a less number, giving about 1600 on each antenna. If these organs are olfactory, we see the reason. The worker's necessity to smell nectar explains all. We, perhaps, exclaim—Can it be that these little threads we call antennæ can thus carry thousands of organs, each requiring its own nerve end? But greater surprises await us, and I must admit that these examinations astonished me greatly. In the drone antenna (Fig. 20) we have thirteen joints in all, of which nine are barrel-shaped and special, and these are covered completely by smell hollows, before and behind, as at C, Fig. 22; each hollow, beside, is somewhat less than those of both queen and worker, being about $\frac{1}{3000}$ in. in length, and $\frac{1}{4000}$ in. in diameter. An average of thirty rows of these, seventy in a row, on the nine joints of the

two antennæ, give the astounding number of 37,800 distinct organs. When I couple this development with the greater size of the eye of the drone, and ask what is his function, why needs he such a magnificent equipment? and remember that he has not to scent the nectar from afar, nor spy out the coy blossoms as they peep between the leaves, I feel forced to the conclusion that the pursuit of the

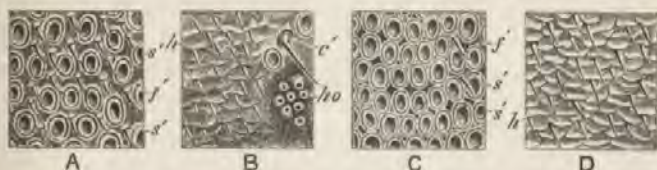


FIG. 22.—PARTS OF SURFACE OF ANTENNÆ (Magnified 360 times).

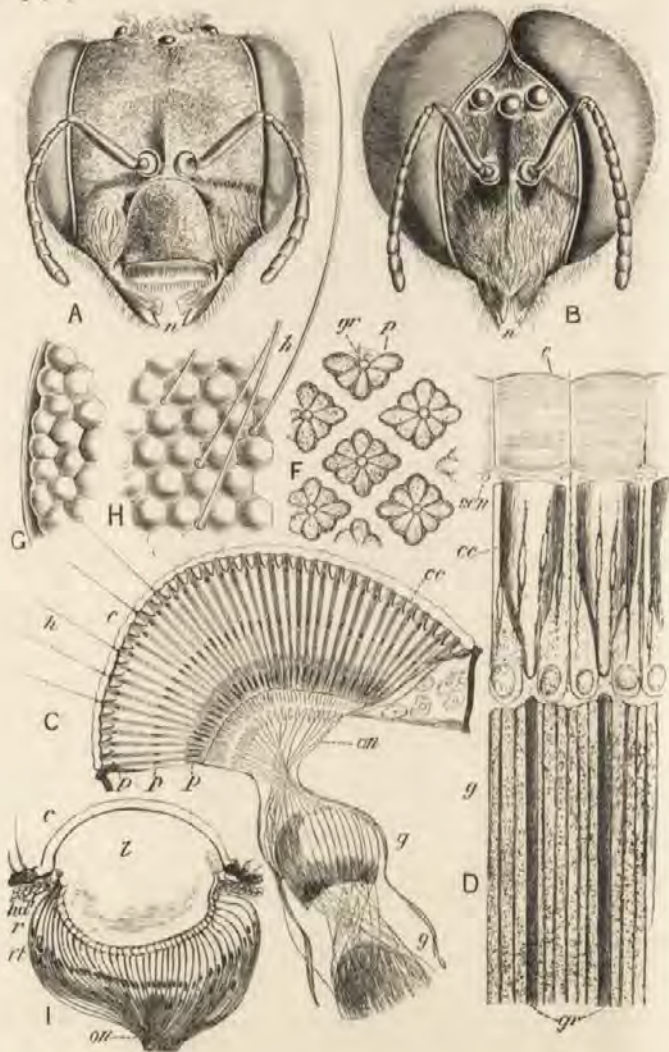
A, Portion of Front Surface of One of the Lower Members of the Flagellum (Worker or Queen)—*s'*, Smelling Organ; *f'*, Feeling Hair. B, Portion of Side and Back Surface of One of the Lower Members of the Flagellum (Worker)—*h*, Ordinary Hair; *c'*, Conoid Hair; *ho* (Auditory?) Hollows. C, Portion of One of the Lower Members of Flagellum (Drone), Back or Front; lettering as before. D, Portion of Lower Member of the Flagellum (Back, Worker or Queen).

queen renders them necessary, and that sight and scent are the faculties by which this is accomplished.

The same wondrous little head that carries the antennæ, with their bewildering multiplicity of parts, bears on its sides the extremely large compound, or faceted eyes (Plate II., or A, B, Plate IV.). The hand magnifier is sufficient to show something of their structure, revealing that the beautiful satin-like appearance they possess is due to their glistening surface being divided into hexagonal convexities (H), disposed precisely like the cells of honeycomb. Each convexity, or facet, is little more than $\frac{1}{1000}$ in. in diameter, and is, really, the outside of an independent instrument of vision. Between most of these

facets we find long, and generally perfectly straight, hairs, which indicate, by their basal formation, that they are sensory, as well as protective, in function. The dark tone of the eye is due to the presence of quantities of colouring matter (technically pigment) within, and as this begins to form during the chrysalis condition, the growing eye then passes through all shades between white and an intense purplish-brown, approaching black. The external lenses, which are, of course, devoid of colour, and very transparent, are chitinous, being developed much as the external skeleton, from an underlying layer, the latter disappearing when they are fully formed. Mutual pressure converts outlines which would, in its absence, have been, in every case, circular, into a series of hexagons—in proof of which, the lenses on the margin of the eye (G) are bounded by a curve wherever they are free; while those of the chrysalis are circular, until they grow sufficiently large to bring pressure upon each other.

If a specimen be properly prepared by hardening, and then cut in cross section, the contiguous sets of parts (ommatidia) are found almost in the form of a fan (C). The superficial lenses, making up together the cornea, are now seen to be bi-convex, while, beneath each, is placed a second lens (the crystalline cone, *cc*, C and D). (For the examination of the cornea and crystalline cones, the directions at page 76 are sufficient; but, for the finer parts, teasing with needles, after soaking the optic tract for twenty-four hours in a 5 per cent. solution of chloral hydrate, is necessary, unless staining and section-cutting, after har-



EYES OF BEES AND THEIR STRUCTURE.

- A, Head of Queen, magnified ten times, showing Smaller Compound Eyes at sides, and three Ocelli on Vertex of Head—*n*, Jaw Notch. B, Head of Drone, magnified ten times, showing Larger Compound Eyes at sides, with three Ocelli between—*n*, Jaw Notch. C, Section through Compound Eye—*h*, Hairs passing through Cornea; *e*, Faceted Cornea; *cc*, Crystalline Cone; *p*, Pigment Cells; *on*, Optic Nerve; *g, g*, Ganglia. D, Longitudinal Section of Part of Eye, magnified 400 times—*e*, Cornea; *scn*, Sub Corneal Nucleus; *cc*, Crystalline Cone; *gr*, Great Rods. E, Cross Section through D—*gr*, Great Rod; *p*, Pigment Layers. F, Facets at Edge of Compound Eye, magnified 200 times. G, Facets of Central Part of Compound Eye, magnified 200 times—*h*, Hairs. I, Ocellus, or Simple Eye—*e*, cornea; *l*, Lens; *hd*, Hypodermis; *r*, Rods; *rt*, Retina; *on*, Optic Nerve.

dening, be adopted.) Beneath the crystalline cones we have the great rods (rhabdia), consisting of several straight chitinous threads, partly fused together (*gr*, D), which pass inwards towards, and actually perforate, the basilar membrane, which is represented by a line running across the lower part of the fan-like form, in the section C. These rods are surrounded, throughout their length, by eight retinulæ, about which are placed pigment cells, preventing the wandering of light from one optic element to another. This will be best understood by the cross section of the rods (F). The crystalline cones, for a similar purpose, are protected by pigment cells, which have also greater density at the upper, lower, and middle portions of the rhabdia (marked *ppp*, C). Between these microscopic telescopes, pointing in every direction, run long and perfectly straight tracheal tubes, which find their entrance by passing through perforations in the basilar membrane. Immediately behind the basilar membrane lies a complex nerve structure, which Dr. Sydney J. Hickson,* in his admirable paper, denominates the periopticon; thence, running backwards, a bundle of optic nerve fibrils (*on*, C), decussate (or cross), and then enter a ganglionic swelling—the epipticon, if we follow the nomenclature of Dr. Hickson. Yet another bundle of decussating fibrils brings us to the opticon (*g* in our figure), beyond which lies the cerebrum, described and illustrated at page 53. The structures united by the decussating fibrils are complex, and

* "The Eye and Optic Tract of Insects." *The Quarterly Journal of Microscopical Science*, April, 1885.

difficult of examination. The periopticon is made up of a number of cylindrical elements, seen just beneath the basilar membrane (C), and consisting mainly of divisions and sub-divisions of the decussating fibrils, traversing a granular matrix, and for which structure Dr. Hickson proposes the name of neurospongium.

All physiological students know perfectly that, in our own eye, by example, vision depends upon the presence of nerve end cells, which lie behind the expansion of the fibres of the optic nerve. The retinulae, previously mentioned, have been very carefully investigated by Grenacher,* and many other naturalists, who have, with great unanimity, regarded these structures as the nerve end cells of insects; but Mr. B. T. Lowne has recently published a treatise,† in which he endeavours to show that the true nerve end cells are situated behind the basilar membrane, in the periopticon of Hickson. The controversy is beyond our limits, and those desiring to follow it may consult the works mentioned in the footnotes.

It is clear at once that the multitude of simple eyes (directed to almost all points of the horizon), which, by partial fusion, constitute the compound eye of insects, permits a far wider range of vision than would have been possible with a simple fixed eye; but difficulties have been felt in explaining how these parts produced a single true impression of surrounding objects. Müller suggested that each ocellus saw only the point just before it, and so a picture was

* "Untersuchungen über das Sehorgan der Arthropoden."

† "Compound Vision and the Morphology of the Eyes of Insects." *Linnaean Society's Transactions*, Second Series, vol. ii., Part 11.

made up in mosaic ; but the remembrance of an observation of Leuwenhoek showed the idea to be untenable. The old Dutchman noticed that each corneule (hexagonal lens of one ocellus) of a fly produced a *complete* image of the flame of a candle, and not a *part* of it. This introduces one of the most remarkable objects that the microscope can exhibit, and which is quickly made from the eye of a bee (although that of a beetle is better). Cut out the cornea, wash it clean inside with a camel-hair brush, place it in water, under a cover glass, and use the flat side of the mirror and a $\frac{1}{2}$ in or $\frac{1}{4}$ in. objective. Focus until all the hexagonal facets are visible. Now gently draw back the objective, when, by daylight, a picture of the window, with its bars, will be seen as formed by each lens in the cornea. If the fingers be put into the right position, their movements can be traced. I have seen thus, simultaneously, in so many facets of the bee's eye, many hundreds of pictures of two houses and surrounding trees, which stood 140yds. from the microscope. At night, if a sheet of tissue, with a watch face roughly drawn on it, be placed in front of the microscope lamp, the time can be seen through each corneule. The picture is *alike* in each ; but then, it must not be forgotten that the cornea is flattened by the cover, so that all the lenses are made to look in one direction. The solution of the question of multiple vision appears to lie in the fact that each ocellus presents a slightly different picture from its neighbour, since its axis is directed to a different point, but that parts apparently overlapping are identical, and so are interpreted into a picture by

the action of the ganglionic structures through which the impressions pass. Those who have best studied the most perfect eyes, know how true it is, that the eye only looks, while that which lies behind it sees.

Besides the faceted eyes, bees carry three simple eyes, called ocelli, or stemmata (I, Plate IV.), on the upper part of the head, although they are not placed quite similarly in the two sexes (*see* A and B). These eyes are very convex, and are adapted to short-distance vision. Behind the simple lens (*I*, I), lie structures much like those found in the compound eyes. Indeed, these eyes, are posteriorly compound, although anteriorly simple. It will be interesting to note, by Fig. 12, page 53, and A, Plate IV., that the cranium is so formed that the lateral ocelli should have a range of vision sideways, while the middle ocellus sees forwards, the hairs being so placed that a clear outlook is preserved.

The possession of the colour sense by bees has been well ascertained, and Sir John Lubbock's* experiments have most satisfactorily shown, not only a power to distinguish between, but a preference for, particular tones. They have no doubt been, in consequence of this faculty, active agents in developing colour in blossoms, as we shall have occasion to discuss in a future chapter; while blossoms themselves, by reaction, have played an important part in augmenting their powers of discrimination.

The large space occupied in the head by the eye structures has been strikingly shown by an interesting case, recently brought to my notice, through the

* "Ants, Wasps, and Bees" (International Science Series).

kindness of Mr. V. Novitzki, who sent me a number of drones, the heads of two of which are accurately drawn in Fig. 23. A is a true albino, the eyes, compound and simple, being alike absolutely devoid of pigment. These drones evidently saw nothing clearly, although they could distinguish light; for, if placed in a box with a small opening, they found the latter at once, and crawled out, but remained captives if

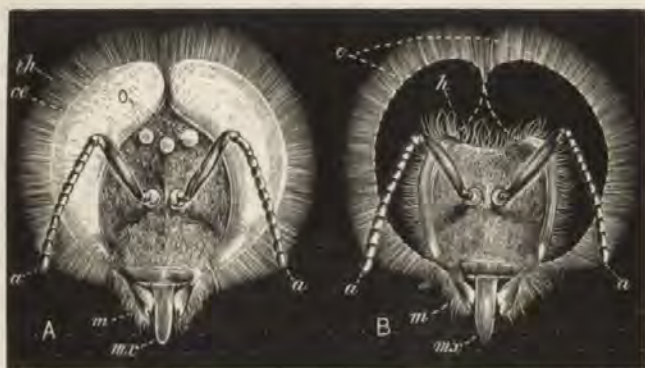


FIG. 23.—HEADS OF ABNORMAL DRONES (Magnified Eight times).

- A, Head of Albino—*ee*, White Compound Eye *v*, White Ocelli; *th*, Tactile Hairs; *a*, *a*, Antennæ; *m*, Mandibula; *mx*, Maxillæ. B, Head of Eyeless Drone—*h*, Hairs; *v*, Outline, showing Size of Head of Normal Drone. *a*, *a*, Antennæ; *m*, Mandibula; *mx*, Maxillæ.

the box was kept in the dark. In the same hive with these drones appeared others with a still more extraordinary defect—no eyes at all existing. The owner represented to Mr. Novitzki that they were headless, and such they might easily have been supposed by a superficial observer. Smooth and hard surfaces, bearing limp, irregular hairs, covered the sides of the head, which did not rise high enough

to include the spot the stemmata would normally have taken. In other respects, the head was perfect; the antennæ, jaws, upper lip, and tongue being well developed. The dotted white line (B) shows the space the eyes should have filled. Since albinism is very uncommon in insects, I have sent specimens of these bees to the Natural History Museum, South Kensington, where they may at any time be seen.

It remains for us to compare the eyes of worker, queen, and drone. Possibly, considerable variation exists, so, for the purpose of comparison, I operated upon bees from the same stock in each case. The worker spends much of her time in the open air. Accurate and powerful vision are essentials to the proper prosecution of her labours, and here I found the compound eye possessing about 6300 facets. In the mother of this worker I expected to find a less number, for queens know little of daylight. After wedding, they are out of doors but once, or at most twice, in a year. This example verified my forecast, by showing 4920 facets on each side of the head. A son of this mother, much a stay-at-home also, was next taken. His facets were irregular in size, those at the lower part of the eye being much less than those near the top; but they reached the immense number of 13,090 on each side of the head. Why should the visual apparatus of the drone be so extraordinarily developed beyond that of the worker, whose need of the eye seems at first to be so much more pressing than his? I have previously suggested the reason in considering the antenna, but facts yet to come before us would render further consideration of the argument premature.

Some writers have described the eye of the bee in a manner which seems to make all easy. Their lenses appear to have been made in a lathe, and run together by pigment which has been poured in between them; but this simplicity has the primal defect of being inaccurate. The eye is gradually evolved from elements incomparably more simple than itself, and which existed in the blind larva. The deep mystery of cell life has caused all to grow into the form the mature eye possesses, but the manner of its building is *still* dimly traceable—cells still compose it, and the pigment is yet but a part of the contents of some of these. Four cells, coming together by the action of that life which is an ever-present miracle, by mutual action framed themselves into the crystalline cone; but the cone still shows its origin, and is not like the homogeneous lens of the optician; and so with every other part, for the eye was and is vital. Every element made out only leads back to some new and more recondite problem yet to be faced. Can we, then, leave these sense organs without being moved by their wonder? Our conception is unequal to the task they give us, although our knowledge of them is, at the best, only superficial. I feel unable to close this chapter as I would. Swammerdam shall do it for me, for he says: "I cannot refrain from confessing, to the glory of the immense, incomprehensible Architect, that I have but imperfectly described and represented this small organ; for to represent it to the life in its full perfection far exceeds the utmost efforts of human knowledge."

CHAPTER IX.

THORAX AND LEGS.

Centre of Movement—Simple Embedding—Freeing the Thorax of Hairs—Legs: Insertion of—Joints: Modifications of—Tarsal Hooks: their Uses—Pulvillus: Uses of; How Cleaned; Automatic Action of; How Folded—Front Legs: Brushes of—Antenna Cleaner: Universally Possessed by Bees—Second Leg Spine: its Use—Third Leg—Wax-plate Pincer—Pollen Brush—Pollen Basket: Its Structure; How Filled—Legs of Queens and Drones—Droll Error—Comparison of Legs.

THE thorax, as the centre of locomotion, giving attachment and movement to both legs and wings, is necessarily nearly filled by large muscles; and these are usually of a pink colour, as may be seen by cutting a recently dead worker, or, better, a drone, down the centre with a keen razor. For elementary study, simple embedding, managed as follows, will be very serviceable: Heat, only sufficiently to melt it, some paraffin or bees' wax, and place in this a few bees. If the temperature be not too high, the longer the "subjects" for dissection are kept soaking the

better. Roll up some wet writing-paper into the shape of a tube, about $\frac{1}{2}$ in. in diameter, lift out the bees with forceps, and drop them, one by one, into it, so that they are arranged end to end. Fill up the tube with the wax, and allow it to cool. The paper being removed, the bees may be cut, in any direction, into very thin slices, for examination.

The thoracic plates have their remarkable external modelling completely concealed by the down which thickly covers them above, and the long, webbed hairs clothing them below. A small patch of these is seen at I, Fig. 24, holding sundry pollen grains between their meshes, the latter accomplishing their purpose by inevitably entrapping the granules furnished by the anthers when visits are paid to blossoms. The queen, as this would lead us to suppose, is relatively bare beneath, but the drone is enveloped in a strong, almost spiny, pubescence, giving him great clinging power, of which the utility is apparent. A little device will make the bees our assistants in studying their thoracic and leg structure. Take a thin string, about a foot long, and at each end fix a dead bee, by tying round the neck. Drop the suspended "culprits" between the frames of a stock, so that the middle of the string rests like a saddle on the top bar. In a couple of days, every hair will be cleaned from the "gibbets," and their bodies polished like those of beetles, so that the attachment of the wings, the spiracles, the lines dividing pro-, meso-, and meta-thorax, the actual form of the leg joints, and the character of their articulations, with many other interesting points, will be clearly visible. All adult

insects have three pairs of legs, which are inserted into the three before-given divisions of the thorax. Those of the bee, with their wondrous quickness

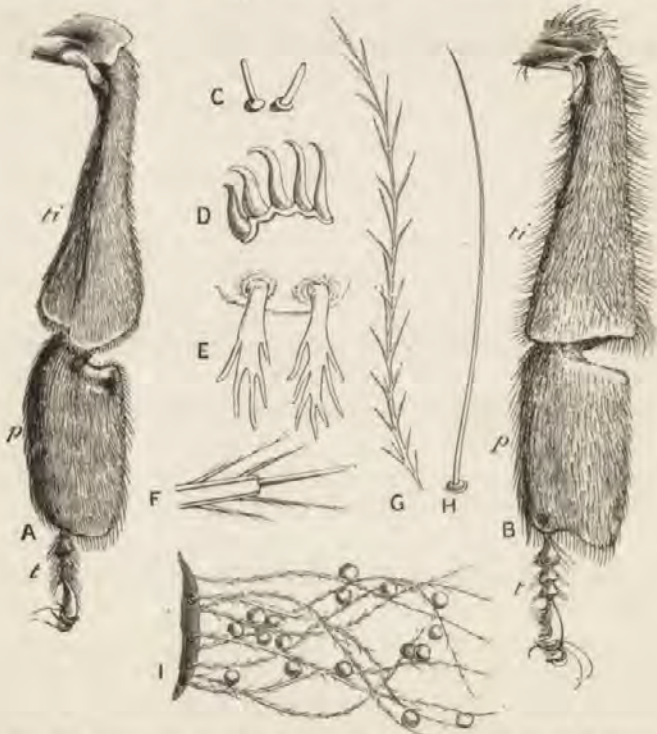


FIG. 24.—DRONE AND QUEEN LEG (Magnified Ten times), AND HAIRS VARIOUS.

- A, Third Right Leg (Drone)—*ti*, Tibia; *p*, Planta, or Metatarsus; *t*, Tarsi.
 B, Third Right Leg (Queen); lettering as before. C, Sensory Hairs from Labial Palpus. D, Ditto from Maxilla. E, Split Hairs from End of Bouton. F, Broken Compound Hair growing anew. G, Webbed Hair for Holding Pollen Grains. H, Long Sensory Hair. I, Small Piece of Under Side of Thorax, carrying Gathering Hairs and Pollen Granules.

and accuracy of movement, may be regarded from two perfectly distinct points of view. First, as instru-

ments of locomotion, from which aspect the several pairs, whether those of queen, worker, or drone, have a common structure, and may be collectively studied; second, as supplying points of attachment and movement to curious appliances, severally distinct in character and purpose, and which, of course, require individual treatment. Let us first examine them in their locomotive capacity. The muscles moving them, and which are energized as explained at page 51, are partly within the thorax and partly within the upper joints; while the lower ones carry only tendons, moved as may be well understood by reference to Fig. 10. Of course, in addition, the legs are provided abundantly with both tracheæ and blood. Each leg consists of nine joints. Articulated into the thorax we find the coxa, or hip (*c*, B, Plate V.), nearly conical, and webbed beneath, and bearing the trochanter (*tr*), triangular, hairy, and firmly articulated to the femur, or thigh (*f*), which is the first elongated joint, and, like the previous ones, very densely clothed by long webbed hairs. It is followed by the tibia, or shank (*ti*), curiously modified in the different pairs and sexes. A foot, or tarsus, of five joints, of which the upper one (the metatarsus, *p*, Plate V. or Fig. 24) is always much larger than the rest, completes the limb.

The surprising power that bees possess, of suspending themselves from the bodies of their companions, and of sustaining a pull, without detachment, of many dozens of times their own weight, which is rendered apparent by the cluster formed in swarming, or in the chains of workers festooning themselves from

the hive roof to its door, at the commencement of comb building, is due to the strong claws, or anguiculi (*an*, Fig. 25), which are found at the termination of the tarsus. These claws, of great strength, bear a secondary talon on the side, and carry long feeling hairs (*fh*). They are capable of two movements. They can be turned upwards, as at B, or point downwards, as at A, Plate V.; and, besides, they can be

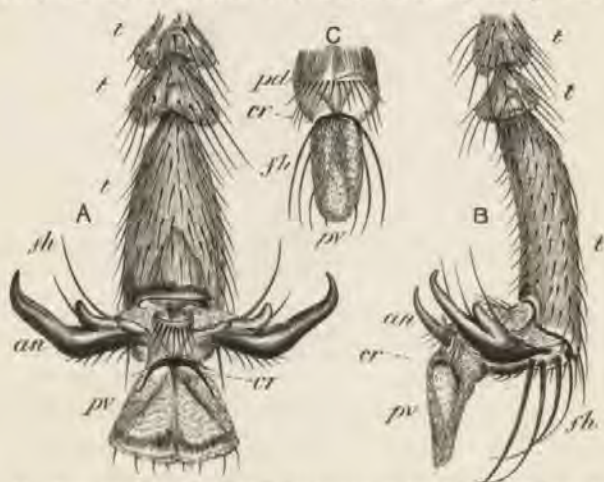


FIG. 25.—FOOT OF BEE, WITH THE PULVILLUS IN USE (Magnified Fifty times).

A, Under View of Foot—*t*, *t*, Tarsal Joints; *an*, Anguiculi; *fh*, Feeling Hairs; *pv*, Pulvillus; *cr*, Curved Rod. B, Side View of Foot; lettering as before. C, Central Part of Sole—*pd*, Pad; *cr*, Curved Rod; *fh*, Feeling Hairs; *pv*, Pulvillus Unopened.

made to approach each other, although not sufficiently to meet. When turned upwards, the perfect support they give to sisters desirous of forming another link in the living chain is evident. By means of these claws, bees walk on the edges of their comb cells, fix themselves on the alighting-board, as they fan in the

summer sun, and cling on to the straw roof of their skep, or the splintery roughness of their wooden hive.

But the tiny foot has yet another power; for bees can, like flies (although not with equal facility), sustain themselves on the polished surfaces of leaves and petals, and upon glass if needs be, although here they get no fixing for their anguiculi. Placing a bee in a bottle, and watching it through a hand magnifier as it ascends the sides, we see between the claws a whitish body (*pv*, A, Fig. 25), which seems to expand, like the camel's foot, as the step is taken. I am not aware that any observer has previously given the pulvillus of the bee attention, yet it is so singular and beautiful that to understand it is to be delighted. All sorts of guesses (for guessing is so easy) have been advanced to explain the fly's walk on the ceiling. Some taught that its foot acted like a boy's sucker, and that the fly was sustained by the pressure of the air; but experiment quickly disposed of the error. The fly can walk inverted on glass in a vacuum, but, if it be moistened, the insect cannot walk on it at all. So with bees: breathe on your glass super, or manage so badly that it becomes moist inside, and its surface altogether fails in affording foothold, for the pulvilli give out a clammy secretion, which is left in minute quantity behind, and I have found high powers of the microscope to reveal its trace. The moisture, of course, prevents this secretion from taking effect. Dusting with flour, or very slightly greasing, just as completely makes perpendicular smooth surfaces impossible of ascent. This will explain why bees so object to plunging into pea

flour, when it is offered to them as artificial pollen (*see* Artificial Pollen), and why, also, they so earnestly clean their legs from all dust. The pulvilli are cleared by rubbing the tarsi together, when the pulvillus is drawn over their abundant hairs, which are, in part, brushes provided for this very purpose. Dredging flour over a bee will start at once this movement, tiny pellets being dropped during the operation, while the tongue is now and again outstretched to supply saliva. Thus, the bee is able, not only to clean itself, but to pack such a dry,

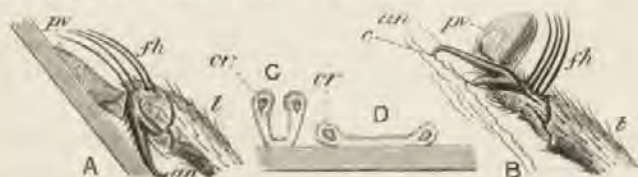


FIG. 26.—BEE'S FOOT IN CLIMBING, SHOWING AUTOMATIC ACTION OF PULVILLUS (Magnified Thirty times).

A, Position of Foot in Climbing Slippery Surface, or Glass—*pw*, Pulvillus; *fh*, Feeling Hairs; *an*, Angulculus, or Claw; *t*, Tarsal Joint. B, Position of Foot in Climbing Rough Surface; lettering as before. C, Section of Pulvillus Just Touching Flat Surface—*cr*, Curved Rod. D, Same Applied to the Surface.

unadhesive substance as pea flour, in beautiful pellets, on its hind legs.

We have seen that the pulvillus cannot be used without loss of material. It is, besides, exceedingly delicate, and easily injured by any roughness, so that it is doubly desirable not to bring it into play where the claws would take effect. I find all this is secured by a most striking automatic arrangement. B, Fig. 26, represents the pulvillus in its rest position, pointing backwards, as it stands between the claws. If the bee is ascending a rough surface, the points of the

claws catch (as at C), and the pulvillus is altogether saved from any contact; but if the surface be smooth, so that the claws get no grip, they slide back, and are drawn beneath the foot (as at A), which change of position applies the pulvillus, so that it immediately clings. It is the character of the surface, then, and not the will of the bee, that determines whether claw or pulvillus shall be used in sustaining it. But another contrivance, equally beautiful, remains to be noticed. The pulvillus is carried folded in the middle (as at C, Fig. 25), but opens out when applied to a surface, for it has at its upper part an elastic and curved rod (*cr*, Figs. 25 and 26), which straightens as the pulvillus is pressed down; C and D, Fig. 26, making this clear. The flattened-out pulvillus thus holds strongly while pulled, by the weight of the bee, *along* the surface, to which it adheres, but comes up at once if lifted and rolled off from its opposite sides, just as we should peel a wet postage stamp from an envelope. The bee, then, is held securely till it attempts to lift the leg, when it is freed at once; and, by this exquisite yet simple plan, it can fix and release each foot at least twenty times per second.

Space compels us to dismiss this part of an inviting theme for the consideration of the legs as tool-bearers, beginning with the front pair of those of the worker (C, Plate V.). The pollen-gathering hairs, and the soft skin, to admit of flexion between femur and tibia, at once strike us; while, upon the front of the latter joint, we note a mass of close-set, soft hairs (*b*), acting as a brush for sweeping the surfaces which the coarser hairs have combed or scraped, and

for cleaning the semicircle of teeth presently to be noticed. At the front of the metatarsus stands a set of long, erect spines, which are always possessed by those bees that have hairs between the facets of the compound eyes. The spines (*eb*) are, really, eye-brushes, or, perhaps, I should have called them combs, since their office is to clear out from the eye hairs all pollen grains or foreign bodies, which would, of course, impede vision. But a most surpassingly beautiful device of the first leg remains to be noticed. It consists of two parts—a deep, curved recess in the back of the *metatarsus*, and a spine and sail, or velum (*v*, C, Plate V.), attached at the termination of the *tibia*. Professor Cook's reference to this marvellous mechanism is so inaccurate in every particular that he is best refuted by quotation. He says: "On the anterior legs of the *workers*, between the *femur* and *tibia*, is a curious notch, covered by a spur. For several years, this has caused speculation among my students, and has attracted the attention of observing apiarists. Some have supposed that it aided bees in reaching deeper down into tubular flowers; others, that it was used in scraping off pollen; and still others, that it enabled bees to hold on when clustering. The first two suggestions may be correct, *though other honey and pollen-gathering bees do not possess it.*" (The italics are mine.) I must remark here, first, that this appliance is not more possessed by workers than by queens and drones; second, it is not between femur and tibia, but where I place it; and, third, it is possessed by every bee in this wide creation,

and also, in a modified form, by wasps and ants. That the use of this appliance has been missed is not astonishing, for the cause of failure is but too evident. If bees be watched (and weary ones on a window-bar are best for the purpose); the first leg will now and again be raised in front of the head, and then drawn outwards. The leg, by this movement, is put over the antenna, which slides up past an especially-contrived slip-way, consisting of the short, stiff hairs, near *p* in Plate V., until the projection of the velum is reached, when the thread-like organ of hearing and feeling drops naturally into the semicircular cavity. At once the tibia bends on the metatarsus, and brings all into the position seen at E; but the antenna is now compassed behind and before, and the teeth of the semicircular comb (standing up towards us in the Plate), as the leg passes outwards, scrape off every particle of dust, rendering all fit again for the delicate duties of smelling and feeling. But the velum, too, aids in the process. Its cross section (*v*, H) shows a back projection, which keeps the scraping edge in position for its work, like the carpenter's plane-body holding the iron. The combs, made up of about eighty teeth, of the form shown at F, are, of course, right- and left-handed; the ends of their teeth, while engaged in scraping, as at *c*, H, always going first. How remarkable the device, and how exact the fitting of parts! I have before stated that the queen's antenna is $\frac{1}{125}$ in. in diameter, and such is the measure of the comb on her first leg; the drone's, $\frac{1}{82}$ in., his comb the same; and so on among both hive and

wild bees wherever I have had the opportunity of taking measurements. These antenna-cleaners are, in all the genera and species, most charming objects for low powers; and Mr. Enock has mounted many at my suggestion, so as to display perfectly their peculiar form. But we must pass on. The second leg has no velum, but a conspicuous spur (*s*) at the termination of the tibia. This spur is the crowbar by which the little forager levers out the pollen mass (*see* page 18), which she carries home, stored in her basket, seen opposite *ti*, at A. The second leg is brought over the third, the spine enters at the top end of the basket, and passes down behind the mass, driving it forwards. This spine likewise aids in cleaning the wings, and so is carried by both queen and drone. The third leg is remarkably specialised, and needs careful examination. The pollen-gathering capacity of the hairs of the upper joints at B is evident. The articulation between the triangular tibia (*ti*) and oblong metatarsus (*p*) is quite at one angle of the two joints, so that, as they move upon each other, the parts opposite *wp* open and shut like a pair of jaws, of which the upper is provided with spiny teeth, shutting down over a flattened plate in the lower. This nipper is exactly fitted to its purpose, and is used for removing wax plates (soon to engage our attention) from the abdomen of the worker. Since neither queen nor drone produce wax, the nipper is in their case absent (A and B, Fig. 24).

But the chief interest centres on the two joints last mentioned, as a device for carrying pollen home to the hive. The metatarsus is enlarged into a sub-quad-

angular form, constituting a flattish plate, slightly convex on both surfaces. The outer face (*p*, A, Plate V.) is not remarkable, but the one next the body (*p*, B) is furnished with stiff combs, the teeth of which are horny, straight spines, set closely, and arranged in transverse rows across the joint, a little projecting above its plane, and the tips of one comb slightly overlapping the basis of the next. Their colour is reddish-brown; and, entangled in the combs, we almost invariably discover pollen granules, which have been at first picked up by the thoracic hairs, but combed out by the constant play of the legs over the breast—in which work the second pair, bearing a strong resemblance to the third, performs an important part.

So soon as bees have loaded these combs, they do not return to the hive, but transfer the pollen to the hollow side of the tibia, seen at *ti*, A. This concavity, corbicula, or pollen-basket, is smooth and hairless, except at the edges, whence spring long, slender, curved spines, two sets following the line of the bottom and sides of the basket, while a third bends over its front. The concavity fits it to contain pollen, while the marginal hairs greatly increase its possible load, like the sloping stakes which the farmer places round the sides of his waggon when he desires to carry loose hay, the set bent over accomplishing the purpose of the cords by which he saves his property from being lost on the road. But a difficulty arises: How can the pollen be transferred from the metatarsal comb to the basket above? Easily; for it is the left metatarsus that charges the right

basket, and *vice versa*. The legs are crossed, and the metatarsus naturally scrapes its comb face on the upper edge of the opposite tibia, in the direction from the base of the combs towards their tips. These upper hairs standing over *wp*, B, or close to *ti*, A (which are opposite sides of the same joint), are nearly straight, and pass between the comb teeth. The pollen, as removed, is caught by the bent-over hairs, and secured. Each scrape adds to the mass, until the face of the joint is more than covered, and the hairs just embrace the pellet, as we see it in cross section at G. The worker now hies homewards, and the spine, as a crowbar, does its work.

Neither queens nor drones gather, and so their legs are quite differently formed. The queen leg (B, Fig. 24) shows, by its outline, that the worker is a female; while the drone leg (A), rounded and smaller, and not carrying even the rudiments of the specialized hairs of the worker, is unlike either. An explanation here becomes necessary, for it may be remarked, that my drone and queen leg, according to some authors, have changed places. It is so, but for the following reason: An old French entomologist published some capital drawings of bees' legs, but his numbering read backwards, since the reversing action of the printing press had been forgotten. He was copied by Blanchard, who, failing to note his authority's mistake, called the drone leg the queen leg, while the latter went to the credit of the drone. Dr. Duncan translated Blanchard,* and, quite innocently, and very pardonably, repeated Blanchard's

* "The Transformations of Insects," Cassell, Petter, and Galpin.

blunder; while Cook, who has taken many of the illustrations in Part I. of his Manual from Duncan, continues to the present hour to publish the error. Surely, after eleven editions, the time has come for breaking the spell, and giving the queen her own legs back again. But, seriously, it is a pity when authors become so fashionable as to slavishly follow the antique. Doubtless, they are saved much time and trouble; but their readers are wronged if they are made to devote their time to obsolete fiction, and unchecked mistakes, when they are led to believe they are studying modern research.

I shall not again refer to Professor Cook's book, nor should I have done so at all, had not the interest of scientific apiculture demanded it.

In comparing the legs of queens, workers, and drones, it is worthy of remark that the queen has by far the largest set, as she is a great walker, constantly perambulating the combs. The drone depends little upon his legs, and so he, notwithstanding his greater weight, carries smaller ones even than those of the worker. They are also but little specialised, their principal peculiarity lying in the hairs of the smaller tarsal joints (*t*, A. Fig. 24), which, in his case, are heavy, and, instead of being simple, are strongly webbed, so as to assist him, as indicated at page 121. The curious adaptations already observed, where none were formerly suspected, makes it certain that future investigations must greatly increase our admiration of such an inconsiderable matter as the leg of a bee.



CHAPTER X.

WINGS AND FLIGHT. BUZZING AND HUMMING.

Development of Wings: Nervures, Cells, and Hairs
—*Wings in Diptera: Reasons for Four Wings in Bees and other Hymenoptera—Hooklets—Posterior Wing not Flat—Comparison of the Wings of the Sexes—Drone can Fly Backwards—Bee Line—Flapping Movement Converted into Flight: Its Velocity—Experiment—Forward Flight—Backward Flight: its Necessity; how Performed—Ascending and Descending Flight—Steering—Wing Rate, Graphic and Musical Determination of—Buzzing and Humming—Obturator Apparatus—Tracheal Distension—Specific Gravity—Sonorous Membrane—Voice.*

THE four membranous wings of hymenopterous insects, articulated in pairs into the meso- and meta-thorax, are formed in the chrysalis from vesicles, or flattened pouches, extravasated or pushed out from the epidermal layer (*see* Fig. 4), and which are brought into form by a series of interior tubes of chitine, called, in the mature organs, nervures, and seen, in Fig. 27, to divide both anterior and pos-

terior wings into cells. The entomological names of those of the anterior wing are given with the illustration, as they are frequently used as a basis of classification.

When, by re-absorption of the contained nutrient fluid, the two facing membranes of each flat pouch are intimately joined, they become the transparent extension of the wing, stretched upon the nervures, which form its stiffening framework. The hollow nervures are never wholly deprived of blood, while through them run large tracheæ, which, at the exit of the bee from the cell, aid it in giving that full expansion to its new organs which their office demands. As the eye has left upon it the marks of its method of development, so the wing gives traces of its origin. The microscope shows that it is dotted over on both sides by small, stiff hairs with an expanded base, while very careful examination reveals that the whole surface is divided, by faint, angular lines, into small areas, which indicate the boundaries of the primary cells, upon the middle of each of which stands a single hair.

Every wing—be it of bat, bird, or insect—that is capable of acting effectively as an instrument of flight, must, in area, bear some definite proportion to the weight of its possessor. The common bluebottle, a dipterous insect, somewhat less than the honey bee, has its single pair of wings of such a width and so placed that their points are $\frac{2}{3}$ in. apart when at rest. Had the bee been similarly formed, its wings would have barred its entry to its own cell, which is only $\frac{1}{3}$ in. in diameter; so that cleaning, filling, and emptying of comb, feeding of brood, and many other essentials,

would have been impracticable. This difficulty, however, is exquisitely met by the necessary wing-surface being made up by *two* pairs, an anterior and a posterior, which lie one over the other in repose, so that they occupy but little space, their two points in position

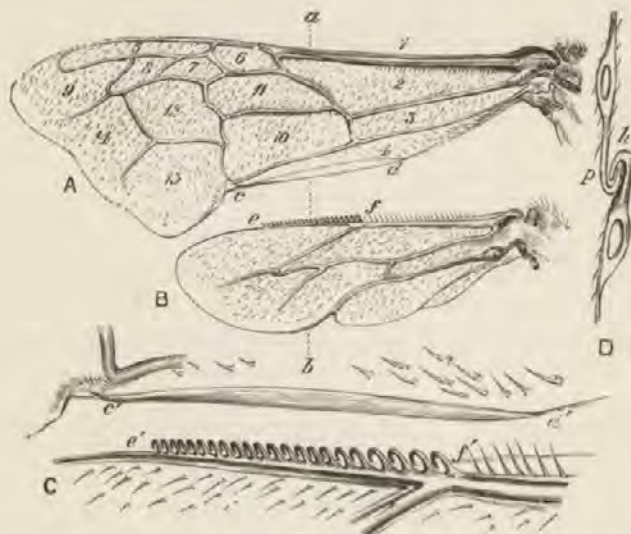


FIG. 27.—WINGS OF THE BEE, NERVEURES, CELLS, AND DETAILS.

A and B, Anterior and Posterior Right Wings of Worker (under side), Magnified Eight times—1, Costal Cell; 2, Externo-median Cell; 3, Interno-median Cell; 4, Anal Cell; 5, Marginal Cell; 6, 7, 8 and 9, 1st, 2nd, and 3rd Sub-marginal Cells; 10, 11, and 12, 1st, 2nd, and 3rd Discoidal Cells; 13 and 14, 1st and 2nd Apical Cells; c, d, Plait; e, f, Hooklets. C, Plait and Hooklets, Magnified Twenty-five times—c', d', Plait; e', f', Hooklets. D, Cross Section through line a, b, of p, Plait, and h, Hooklet, locked together.

only covering a width of fully $\frac{1}{6}$ in. Other hymenopterous insects have, in this respect, a like structure, and for identical reasons: the ant travelling through narrow galleries, the wild bee in its burrow, and the wasp in its cell, being able to so place their wings

that they offer no impediment to their home movements, while the neatness of their packing is in itself a security against damage. The queen of the beehive, indeed, proverbially carries her wings very closely set over the back (*see* Fig. 5), for the greater length of her life demands the greater care; and so the gauzy membranes, in her case, are capable of sustaining the wear of three or four years, yet remaining good enough for duty.

Presently we shall discover that the rate of vibration given to the wings during flight is prodigious, and then the division, so valuable during repose, becomes an impediment, for the air cannot be so efficiently beaten by two narrow wings as by one of their united width. And here, again, a device, charming in its mechanical simplicity and perfection, presents itself. The inner margin (*c, d, A, Fig. 27*) of the anterior wing is folded under, in a plait, while a series of minute blunt hooks (*e, f, B*) are turned up upon the outer margin of the under, or posterior one. As the anterior (upper) wing moves outwards into position for flight, its down-turned plait passes over the upper surface of the lower wing, and is caught by the upturned hooks, as *C* and *D* will make clear; and now the two wings, wedded into one, strike the air: but, at the moment the flying insect settles, these, by falling back into position, become immediately free, since the plait simply slips from the hooks, and the wings take up their superposed position.

The hooklets decrease in size in beautiful gradation towards the wing point—the largest are about $\frac{1}{400}$ in., the smallest, $\frac{1}{850}$ in. in length—but they are not

always the same in number on the two sides of the body. The posterior wing is, most suggestively, not absolutely flat, but convex above, in the direction of its length, so that its hooklets are held up towards the plait on the anterior wings, the hairs just behind which turn in a direction different from the rest, so that the movements of the hooklets shall meet with no impediment. How well Nature rewards looking into even the smallest matters!

A comparison of the sexes is again instructive. The queen is commonly said to have smaller wings than the worker. Yet this is only true relatively, and clearly for the reason that she has much less frequent use for these parts than her ever busy children; but the drone, lighter than the queen, is endowed with that soaring power and rapidity which his function renders necessary, he possessing organs of flight far larger than hers, and which extend beyond the extremity of the abdomen (*see* Fig. 5). The measurements are given in one-hundredths of an inch.

	Length of Anterior Wing.	Length of Posterior Wing.	Ratios of United Area.
Worker	38	28	5
Queen	41	29	6
Drone	49	35	9

The remarkable strength and width of the inferior wing of the drone gives an intimation, which observers should keep in sight; for we shall see presently that this enables him to fly *backwards* with great energy, should such a necessity arise. The relative perfection of the organs is well indicated by the hooklets; and here, again, we find the drone

in the van, and the queen in the rear. The queen's hooklets vary considerably in number, ranging from thirteen to twenty-one; the worker's, nineteen to twenty-three; the drone's, twenty-one to twenty-six.

Bees are accomplished fliers, but they never traverse the air with the same directness as many birds, so that the expression "bee line," used by bee-hunters, needs to be accepted in a modified sense. It is their habit to skim along, in extended sweeps, alternately curving to right and left. The rapidity of their aerial voyages is difficult to calculate. Stories have been detailed of their darting in and out of the windows of a train, in rapid movement, but these furnish no evidence of their velocity when unaided, since the train carries the air lying in its neighbourhood along with it, as leaves and paper scraps frequently make clear. My own observations lead me to suppose that the pace ranges between two and sixteen or eighteen miles per hour, depending upon the load and the nature of the errand—a bee, bearing the body of a deceased sister from the hive, taking the funereal pace, while those issuing forth on business bent go express.

We must now turn our attention to the means by which the mere *flapping* movement of the wings is made to translate the creature through the air, forwards or backwards, at any velocity less than its maximum, and in any direction it may desire.

Fig. 27 shows a strong chitinous rod, called the costal nervure, running along the anterior margin of A; and it is this nervure, carried up and down by the reciprocal contractions of the *depressor* and *levator*

alarum muscles, which moves the membranous extension lying behind it constituting the wing.

A simple experiment, which I would recommend all my readers to try, and which I have often used as an illustration, will make clear at once how this arrangement wafts the insect forwards; but we must be careful to remember, in interpreting it, that the wings in flying are not carried over the back, but are brought round, with their length approximately at right angles to that of the body, so that the costal nerve goes first, and is followed by the membrane. Gum or glue the edge of a

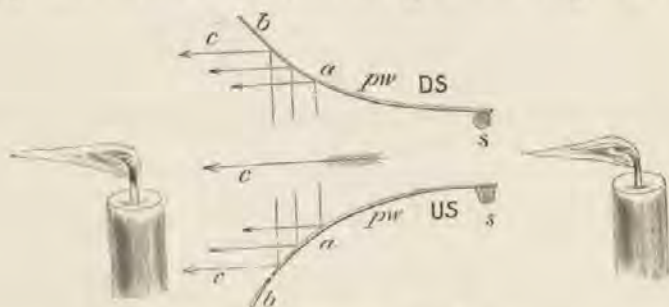


FIG. 28.—EXPERIMENT ON WING ACTION.

pw, Paper Wing; *s*, Stick; *DS*, Down Stroke; *US*, Up Stroke; *c, c, c*, Air Currents.

piece of writing-paper, 3in. or 4in. wide, along the stick of a penholder, or some such form, so that the paper represents the wing-membrane, and the stick the costal nerve. Now place two lighted candles as in Fig. 28, and wave the paper up and down between them, so holding the stick that while it is at rest the paper is horizontal. Both flames will immediately indicate a current from

the stick towards the paper slip. When the downstroke (DS) is made, the resistance of the air throws the paper relatively up, and the air is reflected from its surface, as indicated by the arrows. Similarly, when the upstroke (US) follows, the paper is, by resistance, thrown into such a position that the air is reflected in the same direction as before, so that both ascending and descending strokes give an identical current. Simple mechanics shows that the current from right to left in the Figure, by reaction, tends to move the paper and stick from left to right. Applying this now to the bee, whose pliant wing-membrane yields to pressure like the paper, we learn that both up and down strokes produce a current towards the costal nervure, and from the posterior edge; or, in other words, that the bee's wing itself is moved in space, the costal nervure going first—*i.e.*, the bee flies forward. It is undoubtedly interesting to thus note how both up and down movements aid in progression in one line. Yet this fact but opens up another inquiry, for, if the bee were only able to fly forwards, her plight in its measure would resemble that of a steamship which could not reverse her engines; *they* might be stopped, but *she* would remain under weigh, to possibly compass her own destruction ere her initial velocity had become expended. But a little attention in an apiary will make evident that bees *are* competent to wing their course backwards. As young ones come out for their first airing in the warm mid-day sunshine of spring, they fly constantly looking to the hive door, advancing and receding in curves, so that the head

frequently follows the body. If a bee be watched, too, honey-gathering—*e.g.*, on an apple-tree—she flies rapidly from flower to flower; but, at the exact moment, her hasty advance is suddenly and mysteriously checked, so that she plies her quest by a touch of such measured delicacy, that no filament, however tender, is broken, and no petal unduly pressed. But by what means is this sudden stopping, or this backing, secured? And here we get a deeper insight into the meaning of the small wings than that previously gained; for, although it is clear that they considerably aid in sustaining the bee, from the fact that she can fly *down*, but not *up*, after their removal,

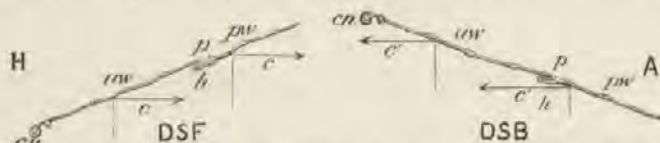


FIG. 29.—SECTION OF WINGS (Magnified Twelve times), to Explain how Flight is Directed.

aw, Anterior Wing; *pw*, Posterior Wing; *cn*, Costal Nerve; *p*, Plait; *h*, Hooklets; *c*, Air Currents; H, Position of Head; A, Position of Abdomen; DSF, Down Stroke, Flying Forward; DSB, Down Stroke, Flying Backwards.

yet they subserve other purposes, by adaptations which cannot fail to strike us as unspeakably beautiful.

In Fig. 28 we observe that the up and down movements of the stick are wider in range than that of the paper, and that its motion decreases as we pass from right to left; similarly, in Fig. 29, where the cross section of the two locked wings is given, at DSF (representing the position at the down stroke when flying forwards) we must note that the large wing has a more extended beat than the smaller, since the latter is the equivalent of that part of the paper

lying between *a* and *b*, Fig. 28. But should the bee desire to reverse her movement, decreasing the energy of the larger wing, and increasing that of the smaller, instantly accomplishes her purpose, without any stoppage of flapping, because the then stronger beat of the small wing, and the restricted beat of the larger, immediately reverses the set of their united plane. By examining DSB, Fig. 29, we shall see the truth of this. Here the wider movement of *pw* (the posterior wing) makes it the leader, producing the alteration that would have arisen from transferring the stick to the opposite edge of the paper (Fig. 28), and the air is, in consequence, beaten in the opposite direction (ϵ'), so that the bee is carried backwards, abdomen first. The up stroke, as before, producing the same current as the down, another Figure is not needed to represent it. The case is that of a screw steamer which, without stopping her engines, reverses her course by changing the direction of the pitch of the arms of her propeller. This, however, is my theory, as distinct from that of Gélieu, which is immensely more complex, and would require a nervous control, which seems to me utterly incredible.

The question of ascending or descending now suggests itself. This has been fully investigated by Marey,* by means of adjustable models, of which our space will not permit a description. Observations on bees themselves have led me to the following conclusions: The wings, during flight, are the points of

* "A Treatise on Terrestrial and Aërial Locomotion" (International Science Series).

support beneath which the centre of gravity, if free to move, always arranges itself. If a ball be held up by a string, the centre of gravity (identical with the centre of the ball, if the latter be of uniform density) comes to rest under the point of support, towards which position it immediately falls after every disturbance. If, in flight, a bee desires to rise, she straightens out her abdomen, thus carrying her centre of gravity (or weight) backwards, and, as a consequence, the abdomen, with regard to the rest, sinks, and the head points upwards, the body revolving around the wings, so that the before-mentioned centre of gravity occupies a position beneath them. This alteration in the direction of the body makes the flight one of ascent. But, on the contrary, curling the abdomen beneath, by the action of muscles lying in the thorax under the meso-phragma, brings the centre of gravity forwards, and allows the head to relatively sink, and a descent in flight is the result. It is possible that the abdomen, acting after the manner of a rudder, also occasions, similarly, all lateral changes of direction. It certainly partially effects these movements, but whether assisted by inequality in energy of the right and left wings, steering as the sculler does, is not yet determined.

The marvellous velocity with which the wings of most insects vibrate has excited considerable attention, and has been tested by most ingenious experiments.

Let us first refer to what is known as the "Graphic method." A metal drum, revolved by clockwork, is

surrounded by smooth paper, which has been coated, by exposure to a smoky flame, with a thin and easily-removed sooty deposit. If a living insect be so held that the wing in vibrating just touches the paper while the drum is rotating, a series of scratch-like marks, equi-distantly placed (*c, d*, Fig. 30), will indicate, by the spaces between them, the amount of movement made by the drum during the time occupied by each vibration of the wing. This time is accurately determined as follows: A tuning fork, whose note (and, consequently, exact number of vibrations per second) is known, has one of its prongs



FIG. 30.—GRAPHIC REPRESENTATION OF RATE OF VIBRATION OF BEE'S WING. *a, b*, Line Made by Tuning Fork; *c, d*, Marks Made by Vibrating Wing.

provided with a small pointed style. The latter, at the moment the insect is being operated upon, is brought into contact with the revolving drum (the fork, of course, sounding), and is so held that the style moves up and down upon the sooty paper. A waved line (like *a, b*, Fig. 30) is produced, the length of each wave marking the space traversed by the drum while the fork makes one vibration. Should the fork give 256 vibrations in a second (sounding the middle C), 256 waves will occupy the space moved through by the drum in the same time. If opposite to these should stand 190 dots made by the bee's wing (*c, d*, Fig. 30), we get 190 vibrations per second as its rate—the

result at which Marey arrived. Tremendous as this speed appears, involving a sequence of muscular contractions of almost inconceivable rapidity, it is probable that it is considerably below the truth, both because of the weakening effect of the experiment and the friction of the paper; Marey finding that, as he lessened the contact of the wing on the drum, the velocity very considerably increased.

These objections do not attach to determinations based upon the note the flapping wings produce. From what has been said of the tuning fork, it will be remembered that pitch depends upon the number of vibrations in a given time, and as the note formed by the wing of the bee in vigorous flight, according to Landois,* ranges between the A and C of the first and second ledger of the treble clef, its velocity, if this musical determination be accurate, can be no less than about 440 vibrations per second, instead of 190, as reached by the Graphic method; but Landois himself observes that fatigue has a marked effect, quickly bringing the rapidity down to three-fourths of its normal amount.

In this connection it is worthy of remark, that bees in the full vigour of youth and health are not always in a condition in which flight is possible. They may, now and again, be noticed to content themselves with *running*, although frightened, even touches with the finger at first inducing no more than flying jumps of 3in. or 4in. Their temporary inability is due to the small amount of air the

* "Die Ton- und Stummaparate der Insecten. Zeitschrift für Wissenschaftliche Zoologie, 1867," page 105.

tracheæ contain at the time. They are at rest, the blood is moving slowly, the body is specifically heavy, and the muscles are not braced up; but after the wings have been lifted, and a few energetic movements of the abdomen made, the vesicles and tracheæ, which just before were flat as ribbons, get filled, and the bee sails away. In many practical operations, bees may be shaken down from their combs in

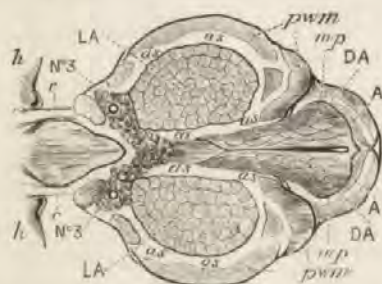


FIG. 31.—LONGITUDINAL SECTION THROUGH THORAX OF DRONE
(Magnified Seven times).

LA, Levator Alæ (Wing-raising) Muscle, showing Fasciculi, or Fibre Bundles; DA, Depressor Alæ (Wing-lowering) Muscle; A, Antagonist of Depressor; *pwm*, Posterior Wing Muscles; *mp*, Mesophragma; *as*, Air Sacs; No. 3, Gland No. 3; *c*, Cervical or Neck; *h*, Part of Head.

a mass, scooped up in spoons or shovels, and weighed and measured in open vessels, pretty much like seeds; the facts just recounted going far to explain the reason. The utility, beyond the purposes of flight, of filling up with air, and the method of its accomplishment, are both interesting and curious. Fig. 31 gives a section through the thorax of the drone, showing the muscles of flight, surrounded on all sides by air sacs (as), from which pass very numerous tracheæ (page 42), supplying the abundant oxygen these most active muscles re-

quire. As DA (the wing-depressors) contract, they pull the mesophragma (*mp*, and page 88) forwards and upwards, and away from the metathorax. The separation of the two walls of the air sac lying behind the mesophragma draws in a supply of air, which, at the relaxation of the depressors, is distributed to the tracheæ, as the antagonist muscles (A) replace the mesophragma, and *rapidly* drive all the air from the air sacs. Other movements aid in the work, so that the initial efforts of flying, as a natural result, distend the body, and bring about all the conditions the absence of which we just now noticed as making soaring impossible. We shall presently see that the bee has perfect control over the spiracles, closing them at pleasure. When on the wing, then, with the air sacs fully filled, if the spiracles be shut, the power is gained for discharging the contents of the bowels by simple pressure, the latter being applied by contraction of those muscles which govern the abdominal rings. That bees labour without weariness in banishing every vestige of impurity from their hives, which, under natural and healthy conditions, they never soil, has frequently been remarked. But these most cleanly creatures are, in this latter respect, *structurally* compelled so to be, from the above-given curious arrangement. The queen is an exception, so far as her capability of removing the intestinal residua is concerned, as her ovaries occupy the space taken by a pair of large air sacs in the worker and drone; so that she on foot, and for an obvious reason, possesses the power (pages 71 and 84) the others only acquire when on the wing.

Every practised apiculturist knows that both workers and drones emit a tone during flight, which is subject to considerable variations, and that these often furnish some indication of the particular "frame of mind" of the insect at the moment. The reasons for some of these differences have already been hinted, but it would be extremely erroneous to conclude that the wings alone, or even mainly, give out a note, in proof of which an easy experiment may be cited. If one of the larger Humbles—*e.g.*, *Bombus terrestris* or *hortorum*—be shut in a box, after removal of the wings, or after they have been so gummed as to be incapable of movement, a humming note will still be produced, which, under the excitement of fear or anger, may be even violent; anatomy showing that this sound, which accompanies the true tone of flight, results from a membranous vibration in the spiracles, the latter being, amongst honey bees, especially developed in the drone, whose sonorous qualities were referred to by Shakespeare. Landois, to whom reference has previously been made, recognised three tones in the flight sound: the first, produced by the wing beats; the second, sharper in character, by the vibrations of the abdominal rings; the third, the most acute and intense, from the action of the true vocal apparatus, placed in the stigmatic orifices. He found that stopping these orifices with wax brought the humming to an end at once. The wings undoubtedly do the buzzing, but the humming is as clearly the outcome of an apparatus formed as follows: The spiracles (page 33) have each lying behind them, in a vestibule (or sounding-box) made by an enlargement of the commencement of

the tracheal tube, a chitinous "stirrup," or crescent-shaped piece, the object of which is to give the insect the opportunity of voluntarily closing the air openings, and this for a before-mentioned reason. A double lever, formed of two irregular and unequal cones, and actuated by an obturator, or closing muscle, and tendon, is so contrived that the contraction of the muscle causes the plugging of the trachea opening out of the back of the vestibule. The sound is actually emitted by curtains, somewhat plaited and fringed, formed from folds of the membrane lying behind the edges of the spiracle, and in front of the stirrup and lever. Muscular contractions within the thorax, occasioning the wing vibrations, rapidly puff air in and out, and so start the curtains in producing that hum, which varies according to their tension, and which may not inaptly be called the bee's voice, since it results from the movements of an apparatus not unlike that of voice in ourselves and the higher animals.

How many wonders are involved, then, in simple flight! The floating of the little insect, as it plays in the sunbeam, or the rapid transport of it at plenty's distant call, enabling it to round a thousand corners, and drop with the greatest accuracy into the mouths of countless flowers, with the wafting of it back again to its desired haven, singing, as it goes, from many mouths, is not accomplished without the framing of a mechanism which is all worthy of our admiration, and which has actually excited the envy, whilst it has mocked, and is mocking, the inventiveness and resources, of mankind.

CHAPTER XI.

SECRETION OF WAX, AND BEE ARCHITECTURE.

Réaumur's Hypothesis—The Discovery—Dr. J. Hunter—François Huber and Burnens—Wax Pockets—Wax-yielding Membrane—Queen and Drone—Microscopic Examination—The True Gland: Its Structure—Wax at First a Fluid—Wax Scales—Wax of Comb—Wax Produced from Saccharine Substances, not Pollen—Huber's Experiments—Comb Building Exhausting—The Behaviour of a Swarm—Conditions Favourable to Producing Fat and Wax—Structure of Comb—Model Making—Cramer's Demonstration—Angles—Economy in Space—Equality of Solid Angles—Maraldi's Calculation—Strange Myth—Bees Capable of Modifying Comb—Suitability of Hexagons—Soap-bubble Experiment—Costliness of Wax—Queen Cell—Covers of Honey not Air-tight; Why Irregular—Sizes of Cells—Drone Cell Peculiarities—Breeding Cells always Approaching the Ideal Form.

THE opinion formed by Swammerdam and Maraldi, and accepted by Réaumur, that pollen, which he called crude wax (page 16), was submitted to a peculiar elaboration in the stomach of the bee, whence it was

returned to the mouth as true ("*véritable*") wax, was completely overthrown by a French peasant,* whose name, unfortunately, has not survived, he discovering, in August, 1768, that the substance used in the construction of comb emanated from between the rings of the abdomen. This humble inquirer, a member of a society of bee-keepers founded in Lusace even at this early date, appears, after having pulled some bees from comb they were then building, to have removed their wax scales by the aid of a needle; but his pregnant observation slumbered for twenty-four years, when Dr. John Hunter† partially investigated the subject, and drew attention to the existence of wax glands. In the following summer, the blind François Huber, justly admired for his researches, and deserving the honour of all good men for his noble acknowledgment of the immense help he received from his servant Burnens, repeated the discovery of the peasant, and entered upon a series of experiments and observations which will keep his name green so long as apiculture is practised.

We already know that the abdomen of the worker is arranged in six dorsal and six ventral inelastic plates, which may move upon each other, because they are united by delicate membranes, giving to the whole the arrangement of the tucks of a child's frock. The exposed part of each ventral plate is tough, and covered by webbed hairs (*wh*, Fig. 32), which much decrease in size towards the anal ex-

* Langstroth makes a prior claim for Hornbostel, in 1745, but he gives no details of what was seen.

† "Philosophical Transactions," 1792.

tremity; but if the abdomen be elongated by gentle traction, we begin immediately to catch sight of extremely smooth and delicate expansions (W, W), upon which, very generally, in the warm season, wax plates of greater or less size and thickness may be discovered. These pale yellow tender discs, which have sometimes been called, quite incorrectly, the wax glands, are eight in number, being found on the



FIG. 32.—ABDOMINAL PLATE (WORKER), UNDER SIDE, THIRD SEGMENT
(Magnified Twenty times).

W, Wax-yielding Surface, covering True Gland; *s*, Septum, or Carina; *wh*, Webbed Hairs.

four ventral plates intervening between the first and last. They are surrounded and held in position by a frame-like thickening of the plate itself (Fig. 32), while between them runs a septum, or carina (*s*). The contour of the membranes determines the form of the wax scales, which are moulded upon their surfaces as the secretion passes, by osmose from the true glands beneath. The hinder part of each

O

ventral plate covers the membrane of the ring next it, forming with it a little pouch (wax pocket), opening backwards, from which the wax scales often protrude a considerable distance. The queen and drone, on the under side of the abdomen, are in this respect quite differently formed from the worker, wax glands being entirely absent in their case, since they take no part in comb building. The plates of the queen (B, Fig. 33) are wide, to give her greater

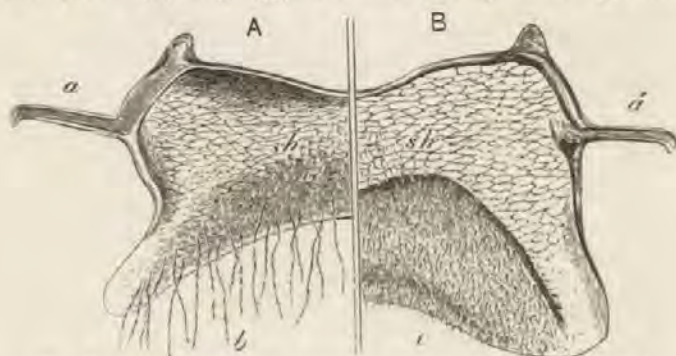


FIG. 33.—ABDOMINAL PLATES, UNDER SIDE, THIRD SEGMENT (Magnified Twenty times).

A, Plate from Drone—*a*, strap; *b*, Webbed Hairs; *sh*, Short Hairs. B, Plate from Queen; *a'*, Strap; *c*, Down; *sh*, Short Hairs.

length of body, while the webbed hairs are wanting, since these would interfere with ovipositing, and no carina exists. The corresponding plate (A) in the drone, though strongly framed, is narrow, because his abdomen carries seven rings instead of six. Loose but stout webbed hairs are provided, for reasons previously noticed, and the process (*a*) giving attachment to muscles aiding in abdominal contraction is much stronger than that (*a'*) possessed by the queen.

Examining, by a medium power of the microscope, the wax-yielding surfaces, as removed from a bee's body, an appearance is presented not unlike that of B (Plate I.); but this is due to an underlying single layer of cells, which, by mutual pressure, are driven into irregular hexagons. After carefully removing the cells just mentioned, I find no evidence of structure in the discs, although, by their character of fracture, they are shown to be double, or to consist of dense faces, with softer material between. The cells, of which there are about 140,000 in the eight glands, when *in situ* are very closely applied to the external discs



FIG. 34.—PORTION OF WAX GLAND, SEEN FROM THE SIDE BATHED BY BLOOD (Magnified 800 times).

tr, main trachea; *n*, nucleus; *o, o, o*, oil-like globules.

(W, Fig. 32), at whose edges they most abruptly terminate. They collectively form the true glands, are each about $\frac{1}{1800}$ in. in diameter, and contain a large nucleus and many small granules, the latter occasionally in movement; besides these, some of the cells seem almost filled up with oily-looking globules (*o, o, o*, Fig. 34); and it is also remarkable, that the part of the surface of each cell which lies next the membrane is raised into numerous minute prominences, needing for their detection careful illumination and the highest order

of objective. The greatest peculiarity of this cell-layer consists in the arrangement and abundance of its small tracheæ (Fig. 34), which do not pass over the upper or lower surfaces of the cells, but travel between their contiguous walls, in such vast numbers, and with such repeated loopings, that constantly as many as five or six interpose in a space which cannot be greater than the $\frac{1}{2000}$ th of an inch. The larger tracheæ (*tr*), supplied from the abdominal air sacs, divide into finer ones, which immediately plunge between the cells, and there take a course which, in the aggregate, amounts to about 60ft. in length. This great need of oxygen for wax secretion is highly suggestive, and will make clear a difficult point when treating hereafter of the chemistry of the hive.

Wax, like every secretion, vegetable or animal, is at first liquid. It is derived from the blood by cell action, and then, transuding the structureless membrane, assumes the solid form of the scale, which, if lifted when the gland is active, will always show that it is fluid beneath. While examining this question, I was struck by finding that the webbed hairs (*wh*, Fig. 32) had their webbings in part or wholly covered by a perfectly fitting casing of pure wax, which could only have arisen by a transference of the secretion, while still fluid, to their surfaces.

Turning our attention now to the wax scales, we find them to differ from the wax of comb. They are much more brittle and transparent, being not unlike flakes of talc. Turpentine dissolves them immediately without residue, whilst fragments of comb disappear but slowly in the same medium, which they make cloudy.

Ether melts wax with difficulty, the scales for a long period remaining in it intact; whilst comb-wax breaks up into minute fragments. When the bee is engaged in building comb, the wax scales standing out beneath the pockets, as we see them in Fig. 35, are removed, as required, by the pincer of the third leg (page 130), which is applied immediately against the body, with the planta (*p*, B, Plate V.) turned from the tibia, so as to widely separate the jaws of the pincers, whose bristle teeth are now passed



FIG. 35.—UNDER SIDE OF WORKER, CARRYING WAX SCALES.
(Magnified Three times).

adroitly beneath the wax scale. The two joints being brought into line, the teeth pierce the scale, which the leg in turn draws from the secreting membrane, to be transferred to the front legs, and thence to the mouth, where it is held perpendicularly, and laboriously masticated with salivary secretion, imparting to it the new and necessary quality of ductility, and bringing about the other changes already noticed.

Huber and Hunter both remarked that the common idea, that wax had its origin in pollen, did not appear to agree with observed facts—*e.g.*, swarms placed in empty hives carry little or no pollen, but nevertheless build combs rapidly; whilst the bees of old hives, which construct no new cells, industriously carry home the many-coloured pellets.

Huber's experiments,* intended to settle the question of the origin of wax, are too important to be passed over. He placed a swarm in a straw skep, and supplied it with honey and water, whilst so shutting in the bees as to permit of full ventilation. The agitation of the captives passed away when their hive was placed in a cool, dark spot. At the expiration of five days, five white and very fragile combs had been constructed. These were removed, and the experiment continued, as it might have been argued that the pollen the bees contained at the beginning of the trial had sufficed to yield the wax. After a further imprisonment of three days, and feeding as before, five other combs were formed. This procedure was repeated to the fifth time with similar results. The experiment was now reversed, a swarm being supplied with pollen, but not honey, and during eight days of captivity neither wax scales nor cells of comb were produced.

Huber had not failed to note that honey contained both minute quantities of pollen and, accidentally, scraps of wax, so his earlier experiment was re-tried upon three swarms. The first received

* "Nouvelles Observations sur les Abeilles," 1814.

clarified sugar syrup, the second dark brown moist sugar syrup, and the third honey. The results, as narrated, were remarkable, and I hope hereafter to test them, for Huber states that, uniformly, during seven consecutive deprivations of comb, the wax secreted by those fed upon honey was far less than that yielded by those receiving sugar, of which the dark brown gave invariably the highest quantities of wax; but these were subsequently equalled by maple sugar. It was thus established, that saccharine matter from the nectaries of flowers, as honey, or in any other form, was capable of furnishing all the material needed for the production of wax. But let us not forget that comb building, even apart from the salivary secretion needed to make the wax plastic, demands muscular and nervous wear, both occasioning a loss of nitrogenous matter and salts—especially phosphates—and these cannot be made up by sugar, which, as a heat and force-former, contains, like wax, only hydrogen, oxygen, and carbon. Physiology and prolonged experience alike, then, show that the effort of comb building is terrifically exhausting to the bee, unless pollen or a substitute is at command, in addition to sugar syrup, or even honey.

It is unusual, as previously observed, to find bees in the summer season without traces of wax in the abdominal pockets, but these are frequently so thin and impalpable that microscopic dissections alone will reveal them. I received by post, on October 22, 1885, a single bee, with a request that I would determine its sex, as it was supposed to be a queen! I found it in all respects a genuine worker; it revived by

warmth, and during five days was regularly fed on thinned honey. Its liberal diet, aided by the cosy solitude I gave it, enabled it to secrete wax, of which I found, at the "post-mortem," eight beautifully transparent scales. This little incident brings before us the external conditions which aid wax secretion.

When a swarm is placed in an empty hive, the bees climb the sides, and gradually, and in close order, advance along the roof, carefully securing themselves by the hooks (*anguiculi*, page 124) of the front legs, in order to sustain the weight of lengthened chains of their comrades, formed by bee after bee hooking her fore feet into the hind feet of the one above. In this manner, the whole swarm will in an hour or so suspend itself in festoons, which are usually in part attached beneath to the neighbourhood of the hive door, in order that an efficient guard may be kept up, and to give ready ladder-way should any arrive with supplies. This arrangement complete, all is hushed in perfect stillness, no bee of the living chains moves, whilst a high temperature is sustained; and now the abundant food with which each emigrant charged herself before she left the old home comes under the process of conversion, and the wax distils copiously on to the surface of the thin membrane in the pockets. Wax is not chemically a fat or glyceride, and those who have called it "the fat of bees" have grossly erred; yet it is nearly allied to the fats in atomic constitution, and the physiological conditions favouring the formation of one are curiously similar to those aiding in the

production of the other. We put our poultry up to fat in confinement, with partial light, to secure bodily inactivity, we keep warm and feed highly. Our bees, under Nature's teaching, put themselves up to yield wax under conditions so parallel that the suitability of the fattening-coop is vindicated.

The wax having been secreted, a single bee starts the first comb, by attaching to the roof little masses of the plastic material, into which her scales are converted, by prolonged chewing with secretion; others follow her example, and the processes of scooping and thinning (presently to receive detailed attention) commence, the parts removed being always added to the edge of the work, so that, in the darkness, and between the bees, grows downwards that wonderful combination of lightness and strength, grace and utility, which has so long provoked the wonder and awakened the speculation of the philosopher, the naturalist, and the mathematician.

The comb (Figs. 3 and 4) is constructed on a middle wall, or midrib (seen in the section at *ab*, A, Fig. 36), which forms the bases or ends of the layer of cells (*c*, *d*) covering it on each side, and which are hexagonal prisms, in length somewhat less than $\frac{1}{2}$ in. The midrib B consists entirely of lozenges, or rhombs (*i.e.*, figures with four equal sides and two acute and two obtuse angles), of which each cell covers three, constituting its base, as may be seen by the double line representing the cross section of the cell sides. The rhombs so meet, with an obtuse angle of each in the middle of the cell bottom, that their edges cannot be joined whilst they lie *flat*, as their enlarged

outline (r, r, r, C) in horizontal position shows. At B, each three is thrown into a concave form. From this it is evident that, if the cells on the two sides of the

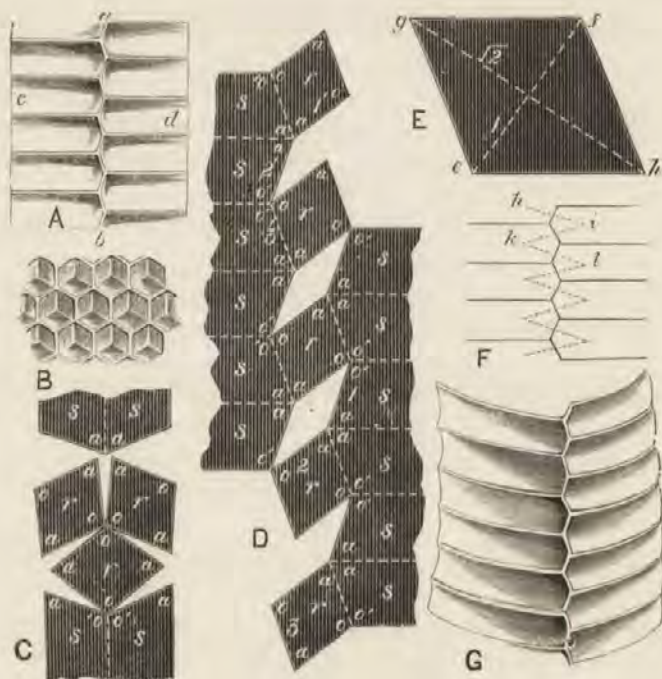


FIG. 36.—COMB STRUCTURE.

A, Section of Comb (Natural Size)— ab , Midrib; c, d , Cells. B, Midrib, consisting of Three Rhombs for each Cell (Natural Size). C, Rhombs and Cell Sides Magnified Three times— r , Rhombs of Cell Base; s , Sides; o , Obtuse Angles of 109° ; a , Acute Angles of 71° . D, Cardboard Pattern, which Folds into Two Cells; Lettering as Before. E, Rhomb Giving Ratios of Diagonals, ef and gh . F, Cross Section of Comb, showing that the Inclination of the Rhomb does not affect Storage Space. G, Section of honey-comb, Showing Curvature of Cells.

comb stood immediately opposite, the concave bases of the one side would present the extreme incon-

venience of convex bases on the other, like, indeed, the bottoms of those bottles which are made to look large and hold little—the very opposite of a principal requisite in comb structure; but equal concavities are given on both faces, by the cell walls of one surface coinciding with the adjacent edges of the rhombs, which diverge from the centres of the cells on the other (*see* A)—an arrangement easily understood by noting that the *single* lines dividing the rhombs in B indicate the lines of the cell walls on the remote side of the comb, while the *double* lines indicate the cell walls on the near side. The same fact may also be made apparent by piercing three pinholes through the several rhombs of the base of any cell, when these holes will be found to belong to three different, though adjacent, cells of the opposite face. Anyone really desirous of thoroughly understanding this, and the other points yet to engage us, will do well to make, in cardboard, the form given at D, where all the obtuse angles (marked *o* or *o'*), and the acute (marked *a*), are equal to one another respectively; the sides (*s*), if extended as far as the edge of the letterpress, giving the correct proportions. The dotted lines being half cut through, the form will fold into two cells thrice natural size, and in correct relative position on opposite sides of the comb, when the edge 1 will fall on 1', and the other numbered edges meet as indicated. Designing a more complicated form, including two cells on each side, and cut out in one piece, is an interesting, and not excessively difficult, puzzle. Strips of gummed tissue paper will hold the cells in form, which, when made

sufficiently large, I have found extremely useful for lecturing purposes.

Supposing that comb equals its ideal or theoretical form, Cramer's* very elegant geometrical demonstration shows that the angles of the rhomb must be such that their two diagonals (ef , gh , E, Fig. 36) are to each other in the ratio of the side and diagonal of a square; or, to use Cramer's less popular, though equivalent, form, the obtuse angle of the rhomb must be such that its half has for its tangent $\sqrt{2}$. This is only true of the angle $54^{\circ} 44' 8''$. The two angles of the rhomb are, therefore, double the foregoing, viz., $109^{\circ} 28' 16''$, and its supplement, $70^{\circ} 31' 44''$. Thence, as geometric sequences, the angles at which the sides of the prism (s , D) are cut at the base, in order to fit on to the rhombs, is precisely equal to those of the rhombs themselves; and, further, the solid angle formed at the apex of the pyramid, by the meeting of the three obtuse angles (θ , θ , θ , C) of the rhombs will be equal to the solid angles formed by the meeting of one obtuse angle (θ) of the rhomb, and the two similar obtuse angles (θ' , θ' , C) of the sides. It is also true, that no other angles give these equalities, which every geometrician will recognise as affording the nearest approach to the form of the larva possible to the number of plane surfaces composing the cell.

It has sometimes been thought that these angles gave greater space than any other; but this is an error, as F will show; for here the actual inclination

* Hutton's "Mathematical Recreations," or Huber's "Nouvelles Observations," vol. ii., page 475.

gives no more room (if the material of the plate be disregarded) than the dotted line (*hikl*), since just so much as is taken out of the comb on the one side is added to it on the other. The real economy is in wax, for, had the midrib been flat, one-fiftieth more of the precious secretion would have been required; the midrib truly taking less, but the sides much more, as the part now cut off from each of them by the inclination of the rhomb must have been added. The strength, also, would have been diminished, while the shape would have been less suitable for the accommodation of a round-ended chrysalis. Maraldi, seeing the advantage of an equality of the solid angles, such as previously pointed out, calculated them upon the hypothesis that they really were equal, making them $109^{\circ} 28'$, and $70^{\circ} 32'$, which is nearly accurate. To the same author we are indebted for a comparison of the results of theory with fact, by the admeasurement of the actual angles of honeycomb. These he states to be 110° and 70° —as near an agreement as could be expected. Out of the details now given, by successive but individually small increments of exaggeration, a most extraordinary myth has been constructed, which, at last, asserts that Maraldi submitted the problem of comb shape to Kœnig, and that his solution differed from Maraldi's actual *measurements, made from comb*, by only 2min. of a degree (whereas Maraldi's results were the outcome of a geometrical hypothesis). The story continues, that Kœnig, being told of this discrepancy, and examining his work for a third time, found an

error in the logarithmic table he was using. Correcting his table, his results came into exact agreement with Maraldi's measurements. Some, like Lord Henry Brougham,* who shows much more of the advocate than the philosopher, have, in consequence, in a triumphant tone, asserted that bees have so absolutely solved a most recondite mathematical problem, that their work has actually corrected a mathematician's press error. A story such as this, once started, is certain of repetition, since, however absurd, it has some sort of superficial prettiness, but, like untruths generally, it degrades what it professes to exalt; so let us examine its claim on our belief. The difference of 2min. of a degree means a divergence so small, that two lines forming this angle would travel 144ft. before separating 1in. from each other. The length of the side of the rhomb being barely $\frac{1}{8}$ in., a divergence of 2min. on the whole length would be about $\frac{1}{140000}$ in., an amount so small that a $\frac{1}{2}$ in. objective would be required to give it visibility; but the field of such an objective is about $\frac{1}{80}$ in. in diameter, and in it not more than the tenth of each side of the rhomb could be seen at once, upon which 2min. would give only $\frac{1}{140000}$ in., a distance which the magnificent quarters now produced, even under the most favourable conditions, would be hopelessly unable to resolve. The conditions, however, are most adverse, while the comb, as a manufactured article, is extremely rough, and, under a quarter, as irregular in surface as the mud wall of barbarism. That Maraldi, with the poor appliances of his day, did measure

* "Tracts, Mathematical and Scientific." Griffin, Glasgow, 1866.

the angles of comb to minutes of a degree, needs no contradiction.

The story is not distortion; it is simple fable—a fitting companion to "Jack and the Bean Stalk," *et hoc genus omne*. But the whole thing is made the more preposterous by the inexactitude of comb itself. Careful measurements of the finest pieces I have discovered, built with every advantage for securing regularity, have shown that every cell is far from geometrically accurate. It is difficult to find a hexagon presenting errors of less than 3deg. or 4deg. in its angles, or, on an average, a distortion more than a hundredfold as great as the 2min. in question.

But because comb presents irregularities, must we think less of it, or the little creature that moulds it, or of the frame of nature of which the latter forms a part? Assuredly not; for if comb, to be perfect, needed that kind of perfection which defective reasoning, and an imperfect acquaintance with facts, would have us to believe it to possess, then the inclination of the brood cells (Fig. 4), and curvature of the honey cells (G, Fig. 36), suiting them so much better to their purpose, would have been impossible; and equally so, amidst many others, the fluctuations in form to suit the character of the bee domicile, or irregular transition cells to mingle drone comb with worker. The instinct of the bee transcends the mathematical solution that has been demanded in achieving its true aim, which is economic. *All Nature, apart from the mystery of life, solves everything mathematically.* The cricket ball flying from

the bat of the tyro, the spray from the maiden's mop, the tiny soap-bubbles of the laundress's lather, as much conform to perfect mathematical solution as the path of a comet or the form of a star. One November morning, about twenty years since, in my early bee-keeping days, I found a skep turned over on the ground, whither it had been knocked by the scamper of a would-be burglar, who had to make his escape before a vigilant representative of the law. The bees, half benumbed, were crawling over their combs, which showed but too plainly that they were broken from their attachments. The difficulty was beyond my powers. *Now* I should run a skewer through the skep, and thread the combs upon it without removing them, but then I judged it best to lift the combs as nearly as possible to the perpendicular, put little wooden props between, place the floor-board over all, and turn to the erect position, hoping for the best; but, alas! the latter operation was followed by a sound which filled me with dismay—the combs had fallen! I studiously fed, the bees lived on, and, in the end, did well. But, by early spring, their combs were a study. One was flat on the bottom board, and was channelled beneath, until it gave passage way in every direction. The others, half down, were propped, and gnawed, and repaired in such a way that their utility was not much lessened; while, from the roof, new combs were made to descend and join in sweeps into their obliquity. I repeat, the mythic measurements of Maraldi would degrade bee architecture. The very atoms with which life deals yield mathematical results

always, but life so mingles and co-ordinates these that the mathematics is masked, while her purposes are secured.

Notwithstanding the absence of mathematical uniformity in comb, it is manifestly a disposition of parts of all others best calculated to afford a maximum of strength with a minimum of labour, and the greatest space for each cell, the quantity of material being considered. On a plane surface, where a number of small and similar spaces are to be divided off by partitions, the hexagonal form is the one which comprehends the largest area compatible with the extent of the lines which inclose



FIG. 37.—WORKER'S JAW (Magnified Twenty-four times).
gfm, Great Flexor Muscle; *a*, Cutting Edge; *sc*, Wax Scales.

it; for the equilateral triangle, the square, and the hexagon, are the only regular figures which admit of being joined without interstices, and the proportion of the area to the periphery of every regular polygon increases as the figure consists of a greater number of sides, and is, therefore, greater in the hexagon than in either of the other two; besides, either a triangular or square cell would form a most unsuitable nest for a chrysalis with a round body.

But it is time that we endeavoured to understand the manner in which the little artificer proceeds with the wax which we have already seen attached to the

hive roof. She has jaws with a smooth edge (*a*, Fig. 37), for scooping and moulding, and the closed maxillæ, with their polished surface, for a trowel.

As the burrowing wild bee chips out a hole circular in cross section, to admit her body, so the wax-worker carves into her wax, placing the material removed upon the edge of the little pitting that increases before her: but two points are accomplished of which no good explanation can be given; first, that the workers so place themselves that the concavity made by one interferes with that made by her next neighbour; and, second, that, when carving from both sides, the scraping and thinning stops before an actual hole is driven through. This mutual interference forms into hexagons, cells that are always circular in outline at the beginning. Let us try an experiment, the apparatus for which is found in every home. A floating soap-bubble is perfectly globular, because the tension of the soap film covers the contained air by a pellicle of the smallest possible area; but if we transfer the bubble to the surface of a saucer, its own gravity flattens one side. Giving it now a companion, the two will convert their films, where united, into a perfectly flat wall, because the equal tension on its two sides will throw the opposing curves into a path between them. So two bees scooping in contiguous cells, or one bee scooping alternately in two cells, will, as the resultant of two opposite curves, produce a straight side. Let us add to our two soap bubbles five others, so that one occupies the centre, while six surround it. Now, in cross section the central bubble is perfectly hexagonal, while all contiguous walls are

flat, and those that are free curved, just as we discover them to be in honeycomb, where every free wall at the edge of the comb runs in a sweep, although partisans, like Lord Brougham, by example, state the contrary. It has been advanced, in opposition to this view of interference, that the outside cells of the paper-nests of some wasps are angular; but, as Darwin* hints, this is capable of explanation, and I submit that it is clearly due to the necessary working on both sides in alternation of three radiating walls, and really lends confirmation to the position I am arguing. To return to our bubbles. If a second layer be placed over the first, not only will they be hexagonal in cross section, but the superposed parts of the two layers will frame themselves into rhombs disposed in all respects like those of ideal comb. The geometrical relations which embellish the wax tracery of the bee are the necessary result of her mode of proceeding. And mathematics is no more her endowment than it is that of the soap and water we have been considering. These wonders come because the whole creation is founded and sustained by the great Geometer, whose laws of weight and measure neither falter nor vary, so that, for the advantage of man, the experience and observation of the past make him the prophet of the future.

The costliness of wax to the bee, since it can only be produced at the expense of many times its own weight of honey or sugar, has led to great economy, 1lb. of it being moulded into 35,000 worker cells in a case I carefully examined; but an American

* "Origin of Species," chapter vii., "Cell-making Instinct."

writer states that he has noted 50,000 cells framed from the same weight. The scraping is continued until the walls are surprisingly thin; those surrounding the cells I never found thicker than $\frac{1}{280}$ in., while some are only $\frac{1}{400}$ in. The rhombs vary greatly, and are stouter, reaching $\frac{1}{180}$ in. in some cases. Bees will, under certain conditions, employ in comb building shreds of wax which they have not secreted; and it is their habit to use up all nibblings and scraps from neighbouring combs, so that a new structure built between two old ones, containing hatching brood, will be brown from the first, instead of daintily white, the microscope showing it to be not only full of the old cappings once lying over the chrysalids, but to contain their cocoons, crossing and recrossing in countless silken threads, while pollen grains abound, a contamination from which not even the cleanest super-comb is absolutely free.

The colour of a queen cell (A, B, Fig. 3) always resembles that of the comb on which it is built, or by which it is surrounded, because it is mainly made of scraps, and for it little or no new wax is secreted. Almost any material seems to be pressed into the service, so that its great mass be made up, careful searching generally being rewarded by finding, between its layers, some of the cast skins of the contained larva, which, though small, seem too useful to be wasted. Brougham, having dissolved a queen cell in "terebinthine" (turpentine), was sorely puzzled by ("Les Pellicules") the cast skins (*see* page 34), which he did not understand, and for which he could not account; but we must not dismiss the queen cell

without noticing its salient peculiarities. It is circular—the typical form—in cross section, because it is built alone, and is made to grow with the growth of the grub it contains; and even if it have a companion (for reasons given under Queen Raising), such cannot be started so near that interference is possible; and as it is deprived of surrounding support, and exposed to unusual strain—having to bear a cluster of bees crowding round to give “royal jelly,” and maintain temperature—great strength is a necessity, and so the economic labourers, that pare down worker cells to the utmost limit, heap on material till it attains forty or fifty times the thickness they ordinarily allow. Yet their scooping instinct does not desert them, as they pit the queen cell over every part of its surface—an operation which saves material without decreasing rigidity. But what is it that so perfectly counterfeits mechanical wisdom, and prevents them continuing this pitting to the limit reached in building worker cells, which would inevitably wreck the nursing cradle of their future queen, and so, perhaps, absolutely deprive them of all hope of a successor to a lost mother?

Liquid dyes kept within worker or drone cells for weeks, have not, in any case, stained water lying in the surrounding ones, which I have never found other than perfect, notwithstanding the extreme thinness of the walls. The bees labour at *both* sides of the latter, not only scraping the shreds, but rubbing them into complete union with their maxillæ, and this will account for their freedom from faults; but observation has led me to form a different opinion of the sealing

of honey-cells, which in former years I described as air-tight. Most bee-keepers have noted that snow-white sealed honey, if kept in a damp place, changes colour, the sealing appearing to grow transparent, and the honey itself not infrequently weeping. By experiments and a microscopic examination, I have made evident that former ideas were inaccurate, and that not more than 10 per cent. at most of the sealing of honey is absolutely impervious to air. To extract



FIG. 38.—CAPPINGS OF CELLS, VARIOUS.

A, Sealing of Brood Cell (Magnified Thirty-five times)—*c*, Cocoon; *w*, Wall of Cell.
 B, Sealing of Honey Cell (Magnified Thirty-five times)—*a*, Sealing outside;
h, Honey; *w*, Wall of Cell, Intervening Air left Black. C, Sealing of Brood
 Deprived of Wax Shreds to show Cocoon, *Débris*, and Pollen Grains (Spot lens,
 Magnified 200 times).

honey (*see* Extraction), it is necessary to shave off the sealing; and if this be done skilfully, the wax is removed so free from honey as to show at once that the covers have never been in contact with the cell contents. By consulting B (Fig. 38), we shall see the reason of this. The horizontal position of the cells prevents their being perfectly filled first and covered afterwards; but the bees, when the cell

is approaching fulness, cap its lower part, then add honey, and increase the cover, placing shred upon shred, after the manner a turf wall is built, until the process is complete; no smoothing by the bur-nishing action of the maxillæ on the inner side is possible, and so the air (left black in the figure) inter-vening between the irregular tape-like shreds cannot escape, and at the close forms a layer between the honey and its cell-lid, giving increased whiteness to the cover, and preventing also immediate leak, even should a fault remain. The air being cut through in uncapping, the caps are removed dry. Steeping in water for three days a well-finished super contain-ing about 780 cells, all but forty-nine revealed that they were defective, by losing their opaque whiteness; for the honey had absorbed water, and was now in contact with the inner wall. The practical import of this observation will hereafter come before us; but I must, at the moment, remark that the demand for very thin capping, which one or two English "judges" have made, is not wise, while the reason they have given for preferring it is an error as to fact.

Although the bee aims at compact coverings for her honey, the sealing of her brood is made porous for an object (as stated at pages 21 and 22), and, when magnified in cross section (A, Fig. 38), shows the looseness of its texture and the varied character of its material, which is never white, and not even prin-cipally wax, only so much of the latter being used as will bind the scraps and *débris* into oneness. On the back, the cocoon threads (*c*) are seen catching

on to the prominences of the wax shreds or pollen grain. One of these covers (from a drone cell by preference), if washed in benzole, so as to dissolve out the wax, and then mounted in the usual way on a slip, forms a very interesting microscopic object, especially for the spot lens, since this shows the cocoon as bright golden threads on a black ground (C).

The most puzzling of all variations remains to be noticed, for no observer has discovered even the key to the gauging of the dimensions of the cell by the wax worker. It cannot be put in evidence that the size of her body or head, or reach of her jaws, determines it, for, under certain conditions which are perfectly uniform, she discards the $\frac{1}{8}$ in. diameter, and starts constructing cells $\frac{1}{4}$ of an inch between the parallel sides, and these are used for the storing of honey or the raising of drones, and so are commonly called drone cells. The statement, many times made, that twenty-five and sixteen of these respectively cover a square inch is erroneous, as the outline is not square, the correct numbers being as below :

—	Diameter.	Length.	No. on Sq. In. on One Side of Comb.	No. on Sq. Ft. on One Side of Comb.	No. on Sq. Ft. on Both Sides of Comb.
Worker cell	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.	$28\frac{1}{8}$	4157	8314
Drone cell	$\frac{1}{4}$ in.	$\frac{1}{4}$ in.	$18\frac{1}{4}$	2660	5320

The change of size, so mysterious in its cause, cannot be made without disturbing the interfitting of the hexagons, the difficulty being met by the con-

struction of so-called "transition" cells. The name is misleading, and based on a misconception, for bees pass at once from worker to drone, or *vice versâ*, and then build accommodation cells as necessity determines, until the regularity of the new pattern is established. It is singular that the form given to these irregular cells, in all the books I have yet seen, is such as no bee ever did or could construct, as it contains an acute angle bounded by straight lines to the angular point. This matter is not unimportant, for, if the books be believed in,

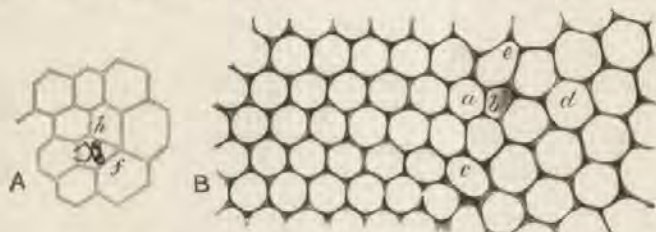


FIG. 39.—CELL FORMS IMPOSSIBLE AND ACTUAL.

A, Impossible Cell—*f*, Angular Point 61° ; *h*, Head of Bee (Natural Size). B, Comb, with Accommodation Cells—*a*, Normal Worker Cell; *b*, Pseudo-Cell; *c*, Oval Cell; *d*, Normal Drone Cell; *e*, Truncated Angle, giving Room for Bee's Head.

the manner of cell elaboration cannot be understood. Even Langstroth, to whom the debt of apiculture is very great, has an illustration of the intermediate cell with a prolonged internal angle of 62° , which a number of English writers have *improved* (?) to 51° , whereas about 100° is the limit the bee can reach. By giving a copy (A, Fig. 39) of the cell (Fig. 48) of Langstroth, into which I insert a bee's head (*h*), of the natural size, the mistake becomes evident; for how could this bee bring her jaws and maxillæ into

the corner (*f*)? as, for reasons previously given, she *must*, and that, too, from the very position in which we have placed her, if the straight boundary lines are to be modelled. The orthodox accommodation cell, which is really partially double, is seen (Fig. 3) above two unsealed drone larvæ, and in it the septem is not continued to the top. A few somewhat irregular forms, in addition to such a one, will enable the bees to pass completely from one size to the other. But even where the greatest difficulties are presented, no angles of less than 100° are found—*e.g.*, in B, Fig. 39, made from a tracing of actual comb, constructed from pieces of drone and worker, placed near to each other, for the industrious little insects to repair and join; a few irregular cells are made to complete the accommodation, the impossible angular point, of course, not transpiring. The nearest approach to an angle lies at *e*, where the width of the bee's head determines the obtuseness, while at *b* the cell is only a depression, not extending to the midrib, because its small size prevents the entrance of the worker's body. Such a cell fills a gap, but is in no other way utilised.

It will be at once remarked, that the normal cells in B stand between hexagons and circles. This is true, more or less, of all comb, which, if cut through in the middle of its cell partitions, shows these to be very nearly straight up to the angles of the hexagons, although some thickening is observable at the line of junction; but the end of the walls, at the face of the cell, is always loaded by a rim of wax, which converts the mouth into an approximate circle. This thicken-

ing of the rim exists in cells at all stages of their progress, since the scraped-off wax is continually added to the edge of the work. As this is reduced, by being drawn out for lengthening the cell wall, it is augmented by new supplies from the wax pockets of the workers. The constancy of these thickenings is essential to impart strength, permitting the clambering throng to support themselves without fear of breaking their own structure, which has its tenacity, when completed, increased by being varnished with a resinous body, called propolis, but whose qualities do not yet come before us.

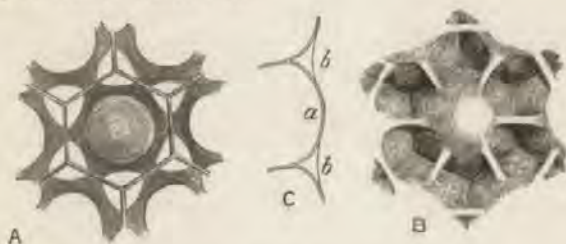


FIG. 40.—DETAILS OF DRONE CELL (Magnified Twice).

A, Capping of Drone Cell, seen by Transmitted Light. B, Capping of Drone Cell, seen by Reflected Light. C, Side View of Drone-Cell Capping (Section)—*a*, Sealing Pervious to Air; *b*, Wax Struts.

The strain which the fragile-looking cells will bear is extremely remarkable. One pound of wax, built into 35,000 cells, as before stated, will store 22lb. weight of honey; from which it follows, that the wax of a cell at the top of a comb, fully filled, and 1ft. deep, supports $22 \times 60 = 1320$ times its own weight. The special manner in which the top cells are strengthened will be most usefully considered under the head "Foundation," in our Practical Section. But drone cells are less rigid

than worker, in the ratio of 25 to 16; so that, in their case, a system of girdering is adopted, which greatly interested me when I discovered its existence a few years since. If a sealed drone grub be dropped backward out of its cell, by cutting away the base of the latter, the capping and its surroundings, as seen by transmitted light, give the appearance of A, Fig. 40. The porous and weak, but semi-opaque, sealing occupies the centre, while the angles are made rigid by filling up with transparent wax, which is done with such regularity that an exceedingly pretty star-like form results; but the little engineers seem not content with this provision, so they throw webs across from the convexity of one cell to the convexity of the next, each web radiating in six arms, as seen at B. The utility of the arrangement as against downward strain is evident, as the strap (*b*, C) clearly prevents any sinking. The illustration shows the almost hemispherical form of the cap, which, we must remember, is made by the bee *outside* the cell, so that the convex side is towards her. How this form is accomplished I know not, and my difficulty is but increased by learning that the contained grub gives no help by its presence within. While studying the drone, I cut, as I imagined, about a hundred of their sealed larvæ from a hive, for dissection purposes. The cappings were fully as prominent as usual, but, to my astonishment, I found *worker* larvæ within, and these only; and searching further revealed the curious fact, that the queen seemed incapable of laying a drone egg, of which more hereafter. The evidence of interference, giving form to worker cells is so con-

clusive to the unbiassed mind, that I cannot help supposing that it possibly applies in this matter. If I ventured on a theory, it would take this form. The throwing up of the cell walls from the three contiguous obtuse angles of three adjoining cells produces the triangular piece (transparent in A), with a depression in its centre, and which an examination of every drone comb (store or brood) will reveal. The worker pitting these concavities forms the wax pieces which strengthen the angles, as previously mentioned, while their edges, naturally becoming prominent, furnish the six straps, by simple junction, when, between the latter, a comparatively flat sealing is thrown across.

Pure wax is perfectly white; the propolis added as a varnish is the usual, though by no means invariable, source of its yellow colour, which *may* depend upon some peculiarity in the nectar the bee is gathering at the time of building; but combs in which breeding has taken place are always more or less brown. This has been explained by stating that the cast skin of the grub causes the discoloration. The cast skin, however, is a delicate and transparent pellicle, and gives *no* colour to the comb. We have already learned that the toning is due to the residua of the bowels, plastered outside the exuvium, within the cell wall. This material at first fills the corners, as may be seen by examining cells in which one hatch only has occurred, when the angles will be dark, while the sides will be only very slightly stained. In this connection, Fig. 4 may be examined with advantage. After a few hatches, all angularity at the cell base

will have vanished, and the cross section will be nearly circular—the typical form, again, to which the cells in this way are always approximating.

The details that have passed before us, and of which hereafter we shall see the practical import, are many and various. Are any disappointed that, during their discussion we have deprived our bee of the mathematical laurels some would force upon her little brow? It cannot be; for surely we have not disgraced her. Rather have we given her new honours, by disclosing adaptations and variations truly astonishing; while all that we have said has not removed her from the front rank of dumb artificers: for even man, with all his art, has not been able to give to wax equal beauty to that it yields at once to the simple tools of its own producer. Yet that which is brick, mortar, and wood, to the bee, must mainly strike us in its utilitarian aspect; for her combs are rows of rooms unsurpassably suitable for feeding and nurturing the larvæ, for giving safety and seclusion during the mystic sleep of pupahood, for ensconcing the weary worker seeking rest, and for safely warehousing the provisions ever needed by the numerous family, and by all during winter's siege. Corridors run between, giving sufficient space for the more extensive quarters of the prospective mother, and affording every facility to the busy throng walking on the ladders the edges of their apartments supply; while the planning of the whole is such that the exactions of modern hygiene are fully met by air, in its native purity, sweeping past the doorway of every inhabitant of the insect city.

CHAPTER XII.

STING STRUCTURE.

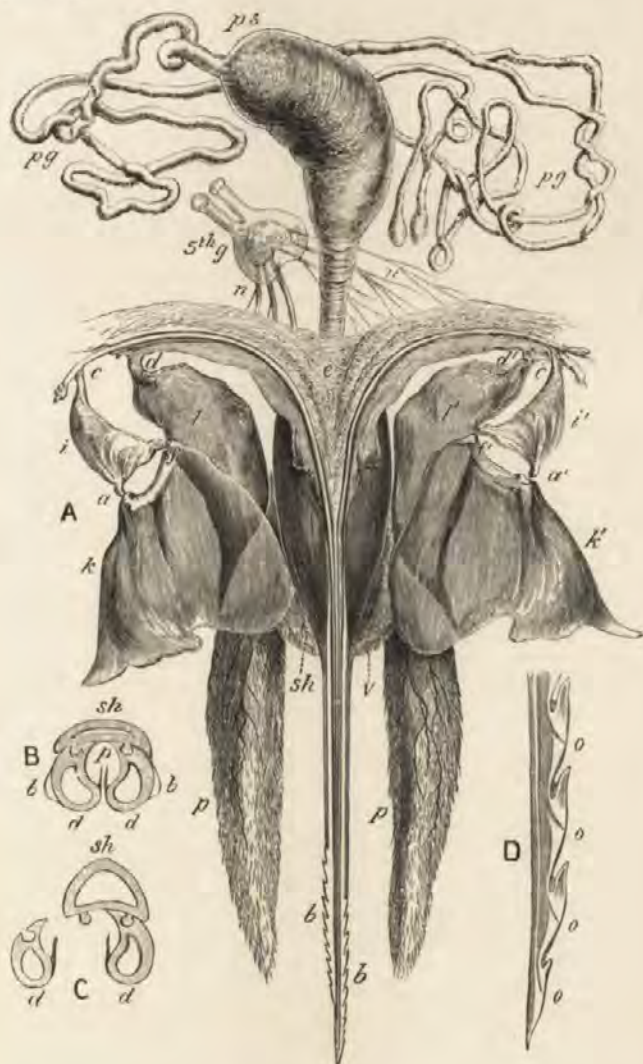
Stings and Ovipositors—The Piercing Apparatus—Sheath, Darts, and Barbs—Groove and Slide Rod—Muscular System—Method of Making the Wound—Nerve Structure—Poison Gland—Formic Acid—Experiment—Poison Bag—Pump-like Action—Removal of Sting—Sting Palpi—Lubricating Gland: Its Secretion; Microscopic Examination—How Friction is Reduced—Queen Sting: Its Size and Modifications; How Planned for Removal; Why Curved; Often Atrophied; Development; Necessity for.

BUT few of those interested in these pages have not, in times gone by, tasted of the potency of the instrument now to occupy us, and the remembrance of its stimulating efficacy, apparently so out of proportion to its size, may quicken our interest as we investigate its structure, which we shall find as complex and remarkable, and equally as suited to its purpose, as those that have already come before us.

Amongst bees, as well as the other aculeate *Hymenoptera*, the sting is exclusively the endowment of the females, and while its primary use is to

arm its possessor, it is also probably helpful in the deposition of eggs. Anatomically, it is analogous to the boring ovipositor of the saw, gall, and ichneumon flies, insects belonging to the same order as the bee. Whilst the ichneumon deposits her eggs in the soft bodies of other insects (which must, of course, first be pierced by her sharp ovipositor), the saw and gall flies have really to cut, by means of rasping teeth, an aperture into leaves, buds, or even timber, so that the eggs may be inserted, together with a droplet of fluid which has a peculiarly irritating effect upon the vegetable tissues, occasioning the production of the galls, which are new growths, that serve not only to protect the larvæ the eggs furnish, but also to afford them nutriment. When we call to mind the strange piercing power of the sting, and its venomous effect, we shall have no difficulty in accepting the statement that the difference between the sting and the ovipositor is rather that of function than structure; they are both situated at the posterior region of the abdominal cavity, the latter being usually carried in a prominent position, whilst the former is always hidden when in repose. Let us now consider the mechanism by which the *worker* bee forms the wound when she strikes.

The piercing apparatus consists of three main portions—a so-called sheath and two darts. The former (*sh*, A, Plate VI., and side view, E, Plate VII.) is a dark brown and strong chitinous piece, large and pouch-like at the upper, but narrowed and flattened considerably at the lower part, where it terminates in an extremely thin cutting edge, which is the



STING OF BEE (Magnified Thirty times).

- A, Sting separated from its Muscles—*ps*, Poison Sac; *pg*, Poison Gland; *5th g*, Fifth Abdominal Ganglion; *n, n*, Nerves; *e*, External Thin Membrane joining Sting to last Abdominal Segment; *i, k*, and *l*, and *l', k'*, and *l'*, Levers to Move Darts; *sh*, Sheath; *v*, Vulva; *p*, Sting Palpus, or Feeler; *b*, Barbs. B and C, Sections through Darts and Sheath, magnified 300 times—*sh*, Sheath; *d*, Darts; *b*, Barbs; *p*, Poison Channel. D, Termination of Dart, magnified 200 times—*o, o*, Openings for Poison to Escape into Wound.

first to enter when the sting is used. The puncture having been made, the sheath is held in the wound by two* rows, each containing three, or unusually six, microscopic teeth (E, Plate VII.), pointing backwards, and acting like the barbs of an arrow or harpoon. The sheath has three functions: first, to open the wound as we have seen; secondly, to act as an intermediate conduit for the venom; and, thirdly, to hold in accurate position the long darts terminated by barbs (*b*, A, Plate VI., and E, Plate VII.). The sheath, so-called, does not inclose the darts as a scabbard, but is cleft down the side presented to us in Plate VI., which is below when the sting points backwards. This cleft at the upper part of the sheath, where the latter is oval in cross section, is just wide enough to permit the two darts to close it by standing side by side between its edges. But as the darts move up and down at their pain-inflicting work, they would immediately slip from their position, unless prevented by a mechanical device, exhibited by B and C, Plate VI., giving in cross section sheath and darts near the termination, and at the middle of the former. The darts (*d*) are each grooved through their entire length, while upon the sheath (*sh*) are fixed two guide rails, each like a prolonged dovetail, which, fitted into the groove, permits of no other movement than that directly up and down, to which we have previously referred. At E, Plate VII., the dart has been

* Mr. Hyatt, who has carefully examined the sting (*American Quarterly Microscopical Journal*, vol. i.), has found only one row, but *two* always exist, although they are difficult to bring into view.

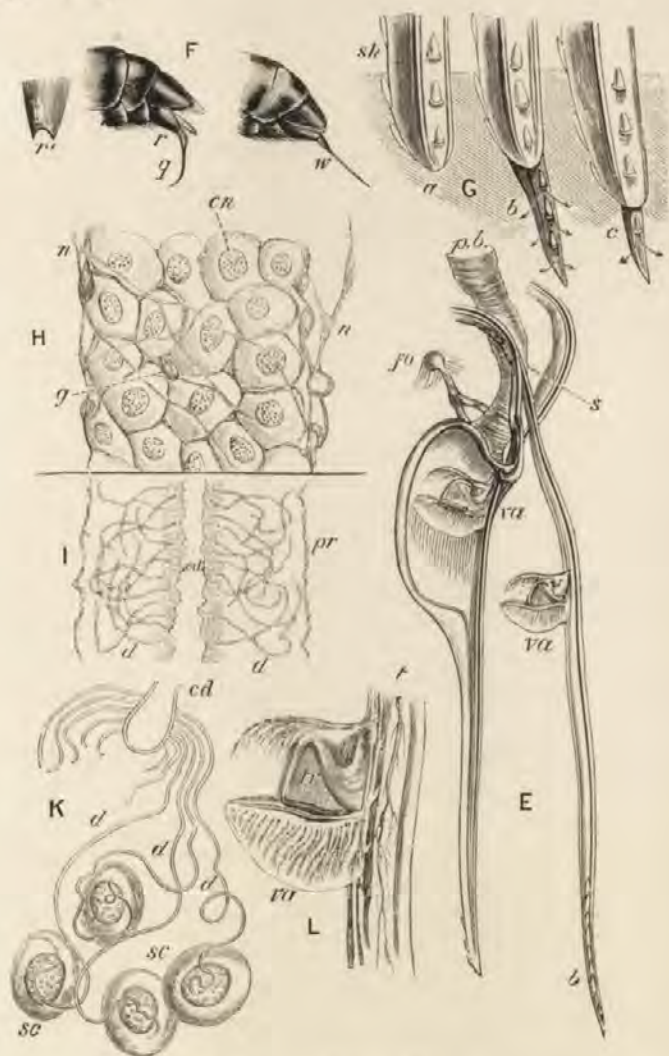
forcibly dragged from its position up to S. The darts are terminated by ten barbs, of ugly form (D, Plate VI.), and much larger than those of the sheath, and, so soon as the latter has established a hold, first one dart, and then the other are driven forward by successive blows. These, in turn, are followed by the sheath, when the darts again more deeply plunge, until the murderous little tool is buried to the hilt. But these movements are the result of a muscular apparatus yet to be examined, and which has been dissected away to bring the rigid pieces into view. The dovetail guides of the sheath are continued far above its bulbous portion, as we see by E, Plate VII.; and, along with these, the darts are also prolonged upwards, still held to the guides by the grooved arrangement before explained; but both guides and darts, in the upper part of their length, curve from each other, somewhat like the arms of a Y, to the points *c*, *c'* (A, Plate VI.), where the darts make attachment to two levers (*i*, *i'*). The levers (*k*, *l*, and *k'*, *l'*) are provided with broad muscles, which terminate by attachment to the lower segments of the abdomen. These, by contraction, revolve the levers aforesaid round the points *f*, *f'*, so that, without relative movement of rod and groove, the points *c*, *c'* approach each other. The arms of the Y straighten and shorten, so that the sheath and darts are driven from their hiding place together, and the thrust is made by which the sheath produces its incision and fixture. The sides being symmetrical, we may, for simplicity sake, concentrate our attention on one, say the left in the Figure. A muscular con-

traction of a broad strap joining *k* and *d* (the dart protractor) now revolves *k* on *l*, so that *a* is raised, by which clearly *c* is made to approach *d*—*i.e.*, the dart is sent forward, so that the barbs extend beyond the sheath and deepen the puncture. The other dart, and then the sheath, follow, in a sequence already explained, and which G, Plate VII., is intended to make intelligible, *a* representing the entrance of the sheath, *b* the advance of the barbs, and *c* the sheath in its second position. The barb retractor muscle is attached to the outer side of *i*, and by it *a* is depressed, and the barbs lifted. These movements, following one another with remarkable rapidity, are entirely reflex, and may be continued long after the sting has been torn, as is usual, from the insect. By taking a piece of wash-leather, placing it over the end of the finger, and applying to it a bee held by the wings, we may get the fullest opportunity of observing the sting movements, which the microscope will show to be kept up by continued impulses from the fifth abdominal ganglion, and its multitudinous nerves (*n*, A, Plate VI.), which penetrate every part of the sting mechanism, and may be even traced into the darts. These facts, together with the explanation at page 49, will show why an abdomen separated many hours may be able to sting severely, as I have more than once experienced.

But it is not the laceration from the sheath, nor the punctured wound of the dart, that makes the insect robber of honey so cautious, nor man so solicitous to conciliate the gracious favour of Miss Apis; for, when the worst has been done, we have

a wound whose maximum depth is $\frac{1}{16}$ in., and whose diameter is $\frac{1}{600}$ in., or less than $\frac{1}{300}$ of the area of that inflicted by a common pin. The sting derives its value, as an instrument of attack and defence, from the poison with which it is associated, and which is derived from a gland (*pg*, A, Plate VI.) having often the astonishing length of $1\frac{1}{4}$ in. in the worker and $1\frac{1}{2}$ in. in the queen. In the former, dissection reveals it travelling, like two attenuated, nearly transparent threads, over the outside of the chyle stomach, while its ends are swollen into forms resembling the plumber's iron. These are full of curious dotted cells, containing granular matter, and are abundantly supplied with tracheæ. The bifid gland unites at some distance from the poison sac (*ps*). Its structure (H, Plate VII.) is in the divided portion intracellular, and the ductlets of the cells (I) may be brought into view by treatment with liquor potassa.

The poison it secretes is formed from the blood by cell-elaboration and transformation, and its active principle seems to be formic acid, probably associated with some other toxic agent. If a bee be made to sting a piece of paper stained with litmus, which is a common test for acids, the dye is immediately reddened. On this account, ammonia is often recommended to allay the irritation a sting causes, as it is argued that the alkali must act as a neutraliser. Formic acid is poison to the *blood* of the bee, which dies by a sting from its relative, although it is not injurious if taken, in reasonable doses, into the creature's stomach, as food mixed with it is accepted readily, while no untoward consequences are observed (*see* Diseases).



DETAILS OF STING OF BEE.

E, Darts, Sheath, and Valves—*p.b.* Poison Bag Duct; *fo*, Fork; *s*, Slide Piece; *ra*, Valve; *b*, Barbs. F, Terminal Abdominal Segments—*w*, Worker's Sting; *g*, Queen's Sting; *r* and *r'*, Anal Plate. G, Sting Entering Skin—*sh*, Sheath; *a*, *b*, *c*, Positions in First, Second, and Third Thrusts with Sting. H, Poison Gland, magnified 300 times—*en*, Cell Nucleus; *n*, Nerve; *g*, Ganglionic Cell. I, Poison Gland, Cells Removed—*cd*, Central Duct; *d*, Individual Small Ducts; *pr*, Propria. K, Gland of *Formica rufa*—*cd*, Central Duct; *d*, Small Ducts; *sc*, Secreting Cells. L, Valve and Support, much magnified—*t*, Trachea; *va*, Valve; *tr*, Truss of Valve Prop.

The poison bag, of considerable size, is lined with epithelium, but is not muscular, as stated by Mr. Hyatt, its venom being driven from it by the play of the muscles giving activity to the apparatus, and by a singular pump-like arrangement, presently to be noticed. Indeed, a comparison of the highly muscular poison sac of the wasp, which has no valvular appendages, with that of the bee, is highly instructive. The poison sac contracts into a strong neck (*pb*, E, Plate VII.), which enters the upper bulbous part of the sheath, in which play the valves (*va*). The walls of the sheath are double, with blood between, while it is into the cavity within the interior lining that the poison enters, and so bathes the back part of the surface of the darts, which stand in the cleft in the front of the sheath, as before stated. Since the darts present concave surfaces to each other, they inclose a tube-like space (*p*, B, Plate VI.) between them, through which the poison passes downwards, towards the base of the wound, being driven forwards by the piston-like action of the valves (*va*, E, Plate VII.), which descend with the stroke of the darts to which they are fixed, and sweep the poison before them, ramming it onwards, when the end of the stroke is reached, by the valve meeting the lower end of the pouch. These valves are remarkable structures, and, with regard to them, I venture to differ absolutely from Mr. Hyatt. It will be remembered that the bulbous part of the sheath is oval in cross section. The greater diameter of the oval runs from front to back, and this space the two valves divide between them,

one taking the right, the other the left, half. As they pass up and down in company with the darts, they never become absolutely clear of each other. Although one be at the top, and the other at the bottom of the stroke, they still, in part, are side by side, so that clashing or interference is impossible. Each is formed from the dart, by the throwing back of two strong, parallel, chitinous, rod-like pieces, supported by a truss (*tr*, L, Plate VII.) above them. As the whole valve is necessarily narrow, the space between these rods is small. Above the truss we find a feathery expansion, in the form of a hood, which really holds in position a most delicate membrane—not represented in the Figure—really a bag, mouth downwards, the edges of its mouth being attached to the parallel rods, so that, when the down stroke is made, the poison, with which the pouch is always full, passes into, and expands, the bag, as a butterfly net is opened out when it sweeps through the air. Below each rod depends another membrane, semicircular in outline, and stiffened by numerous chitinous, branched thickenings, seen above *va*. These flaps, at the down stroke, separate from each other, and the better drive the venom before the advancing valve. At the end of the stroke, the fully-extended membranous bag, by its elasticity, continues to drive on the poison until its companion takes its place. At the upward stroke, the bag collapses, and settles on to its feathery support, which holds it in position for re-filling, while the depending flaps fall together. The accurate fit of the darts prevents the escape between

them of the poison, which is constantly being pumped forwards, as we have seen; but exit is provided by minute channels ($\sigma, \sigma, \sigma, \sigma, D$), passing from the poison cavity to the base of each of the five lower barbs; the poison is thus sunk to the lowest point in the wound, where it collects, so long as the sting remains, until the poison sac is itself empty. From all that has been said, it is apparent that the more quickly the attached sting can be removed, the better. A prompt brushing of the finger over it, or rubbing of the hand, if wounded, rapidly over some part of the clothing before more than a superficial puncture has been made, will usually dislodge the entering sheath; but even if the sheath and darts have descended their full length into the skin, every additional thrust, although adding nothing to the depth of the wound, still pumps into it additional virus.

The bee, quick as thought in the execution of her attack, nevertheless does not inflict a wound until she has examined the nature of the surface to be punctured, using a pair of very beautiful organs (p, p, A , Plate VI.), called palpi, elaborately provided with feeling hairs and thin nerve ends. She is never so mad with anger but that she has method in her madness, preferring animal to vegetable substances for attack. It is extremely difficult to get her to sting writing paper, and some substances (to be mentioned under Practical Management), applied to the skin, will almost, if not absolutely, save it from attack.

The strictly mechanical build of the sheath and darts—reminding one almost of the guide rods of a

steam engine—introduces a question which greatly puzzled me before I found its solution. If some of the virus, exhibited as a tiny drop at the point of the extended sting of an angry worker, be removed by a glass slip, and allowed to dry for three or four minutes, it will become hard, leaving a little prominence, as though it had been gum water; and if it be placed under the microscope as it sets, it will be seen to split, by contraction, into lines, which rapidly travel across the field of view. Dr. Bevan* says: "If the poison be looked at by a microscope, pointed crystals will become visible. These may be seen at first floating in the venom, and gradually shooting into crystals as the fluid part evaporates." Careful experiment proves that Dr. Bevan was probably deceived by a defective microscope. He mistook, no doubt, the fissures for crystals. The object is a curious one, and the experiment so easy that it should be tried. But to our point. How is it that this gummy body, insinuating itself between the grooves and tenons, does not quickly fix them together, and render the sting utterly inoperative? Another gland, not seen in the Figure, prevents what some might consider "a consummation devoutly to be wished." Its place is behind the ganglion; it is much smaller than the poison gland, being about $\frac{1}{12}$ in. long and $\frac{1}{100}$ in. in diameter, and, like its companion, it enters a sac, which is the reservoir of its secretion, and which would be situated behind the vulva (*v*) in the Figure. The fluid it produces is a lubricating oily body, which, entering between the working parts, secures their

* Bevan "On the Honey Bee," 1838.

free play upon each other, while the sting itself has as little contact with the venom as a duck's back with water. The extrusion of the sting brings forward this secretion, which emits the peculiar odour sometimes to be recognised if a number of bees are roused to anger. When the poison is examined through a good objective, the tiny oil globules which have been provided by the lubricating gland are found in thousands. Not only is the clogging of the moving parts prevented by this beautiful system of lubrication, but that friction is greatly reduced which tells so terribly against long rods moving in grooves, especially such as these, only $\frac{1}{50000}$ in. in diameter, and fully 600 times as long as broad. And here I find the very highest degree of mechanical perfection is reached, by not permitting the rod to move in absolute contact with its groove throughout its whole length; for if the rods, at their upper parts (near *c*, *c'*, A, Plate VI.), be torn from their places, they will be found to carry studs, or cogs, at regular intervals, which themselves only come against the back and sides of the grooves, so that they not only diminish the contact surfaces, but act as distributors of the lubricant—an antitype of the plan often followed in machinery required to act with great smoothness and precision. It must, however, here be noted, that good high power objectives are required.

The sting of the queen differs from the worker's in many particulars, although the plan of the structure of both is identical. The worker uses her weapon at great risk to herself, for frequently, and,

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indeed, generally, she loses, not only the sting and the venom gland and sac, but also the lower portion of the bowel, so that her death follows in an hour or two. The queen, whose individual life is bound up with the very existence of the colony, carries a sting which her instinct forbids her to use, except possibly in the sole case of contest with another queen. She may, by violent usage, be induced to protrude the weapon of offence, but never does she in human hands inflict a puncture. The instrument she carries is also especially planned to prevent the catastrophe which so frequently follows its use in the case of the worker, while she receives from it superior protective power because of its larger calibre and greater length, the sheath being able to penetrate $\frac{1}{10}$ in., and the darts $\frac{1}{8}$ in. more, making together $\frac{1}{2}$ in., while the darts are $\frac{1}{400}$ in. in diameter. The sheath is more heavily barbed than the worker's, carrying two rows of retrorse teeth, five or six in a row; but the darts are occasionally plain, though more often provided with three minute teeth, which scarcely rise above the general surface. It will be remembered, that the venom escaped from the worker's sting by tiny holes beneath the lower barbs of the darts. Since the queen's sting is here practically barbless, exit for the poison is given by hollowing out the inner faces of the extremity of each dart into the form of a gouge. When a worker stings, and becomes—as a friend observed—quite unpleasantly attached to us, it will, if allowed time, generally carry its sting away by travelling round upon the wound, giving the instrument a screw movement, until it is free. The queen

has been known, when stinging a rival, to so free herself; and the form of the sheath presents every opportunity, in her case, of securing this desirable object. Its flatness and extreme hardness—for it turns the edge of the finest razor—causes it to act as a drill, so that, after a few turns, a large hole is made, and it is clear, for, when the sheath is freed, the darts offer no impediment.

It has been remarked, that the decided curvature of the queen's sting (*q*, F, Plate VII.), in contrast to the straightness of that of the worker (*w*), is intended to give her such an advantage in combat, that, while her sting is applied, her antagonist should be powerless to reach her, so that a queen duel may not be fatal to both; but the curvature appears to me rather to refer to mating and ovipositing, as the extremity of the sheath can be turned far more completely out of the way through its deviation from the straight line, and the more so because the terminal ventral plate (*r'*) is much truncated, so as to afford a recess into which it can be dropped. It cannot be doubted, that the possession of the sting by the mother-bee of the hive, at the same time that it is generally denied to all but aborted females (neuters), indicates that it has only a relation to some special phase of bee-life, which observation proves to generally transpire before impregnation; and it is curious that, in the great number of queens I have dissected, a marked majority have had the poison gland atrophied, while the poison sac, although distended, has contained only a yellowish substance almost, if not quite, as solid as new putty, and which,

of course, could not have supplied anything to a wound the sting might have produced. Coupling this with the absence of a special ganglion, such as we find in the worker—for the last ganglion is mainly required for the reproductive organs—the very secondary importance of the sting to the queen can hardly be questioned.

The development of the sting during the larval and chrysalis conditions is extremely interesting. Its first indication consists in line prominences, or warts, found in pittings on the ventral side of the penultimate and anti-penultimate segments of the maturing larva (*b, c, A, Fig. 47*); but these are quite invisible until, by hardening with alcohol, they make their appearance beneath the external skin. These increase, and gradually assume the mature form during the chrysalis condition, at the same time that the segments bearing them diminish, especially on the ventral side (*b, c, B*); so that, although appearing at first on two distinct segments, the parts get fused together, and the last segment but three (*d, A*) of the larva becomes the last of all in the bee (*d, C*), the intervening ones being introverted. The residue of the disappearing segments is, at the same time, modelled into the various parts that are accessory to the complex organ, which, from the very manner of its formation, lies within the body, like a sock which has the foot turned inside the leg.

However much we may regard the possession of a sting by a domesticated creature as undesirable, there is no room to doubt its necessity to the bee in a state of nature, where, in its hollow tree, or recess

in a rock, the avenues are wide which would give entrance to the robber. Even with the narrow doorway of a hive, bees are sometimes sorely worried in the fall by the persistent attacks of hungry wasps, that would overmaster any number of brave defenders, were the latter deprived of their poisoned darts. Man, by observation, and a knowledge of the habits of the insect, can nearly always successfully prevent or evade her attack; for it is too much to expect her to concede that the master robs by right divine, or to understand that he but levies a righteous tax upon the prosperity he brings by the refinements of civilization and the wisdom of his government—a failure in which she has been followed by some higher in the scale of creation than herself. There is, besides, a charm in overcoming difficulties. Man was born to conquer; he was placed in the world to “subdue it”; and so the zest of successfully marshalling, at our will, a throng that could, if they knew their power, drive us writhing from their neighbourhood, is far greater (even though the profit might be less) than could come, in the absence of the sting, from the management of—

“A golden hive, on a golden bank,
Where golden bees, by alchemical prank,
Gather gold instead of honey.”

Man and bees alike live in a world where good and evil grow together, where the thrift of the industrious excites the cupidity of the idle, where *meum* and *tuum* are regarded sometimes as convertible. Let us, then, accepting the sting without regret, strive to learn the way in which, for us, it shall cease to be an evil.

CHAPTER XIII.

ORGANS OF THE DRONE.

Function of the Drone—Description of Organs—Production of Spermatozoa—Development of Drone after Imago Condition is Assumed—Microscopic Mounting and Staining—Spermatophore—Armor Copulatrix—Eversion by Finger Pressure—Glove Experiment—Extrusion of Spermatophore: how Accomplished—Fertilisation in Confinement a Failure—In-breeding Prevented—Survival of the Fittest—Death of the Drone—The Queen becomes Double Sexed—Parthenogenesis—Hermaphrodite Bees: Reason why so many are produced—Natural Selection—Drone Slaughter.

BEFORE entering upon a detailed examination of the drone (Fig. 5), we should know something of the position he has to occupy. The queen—whose egg-laying powers have already come before us—on the wing, and when a few days old, mates, but never again, however much her life may be protracted. The drone at this time gives a sufficient amount of fertilising material to secure the individual impregnation of the multitude of eggs afterwards to be laid. To enable him to accomplish this, his organs are, in some respects,

unique, and of most disproportionate size, greatly exceeding those of even the largest *Bombus*, for the



FIG. 41.—ORGANS OF DRONE (Magnified Twelve times).

A, Organs Removed from Body, but in True Relative Position—*t*, Testes; *vd*, Vas Deferens; *vs*, Vesicula Seminalis; *mg*, Mucous Glands; *de*, Ductus Ejaculatorius; *o*, Termination of Organ; *s*, Sickle-shaped Scale, beneath which Spermatophore is formed; *ts*, Triangular Scale; *b*, Bean; *f*, Fan-shaped Appendage; *r*, Ridges (Five-banded Piece of Swammerdam); *h*, Horns; *m*, *Masque* of Réaumur, or Hairy Membrane. B, Spermatozoa Developing within Spermatophore of Testes (Magnified 500 times)—*sv*, Spermatic Vesicle; *n*, Nerve Cells. C, Spermatozoa as they arrange themselves after Removal from the Body—*a*, Coiled Form; *h*, Head; *th*, Thread. D, Face View of Appendage *f* in A—*f'*, Fan-like Fringe. E, Organs Extruded; lettering as A. F, Front View of Portion of Bean—*s'*, Sickle-shaped Scale; *sp*, Spermatophore; *ts'*, Triangular Scale.

egg-producing capabilities in this genus are relatively restricted. Since he has but one function, he is needed only during the months when swarming may be possible, so that, normally, in the winter he is non-existent.

The distinctive sexual organs consist of a pair of testes (*t*, A, Fig. 41), communicating, by narrow tubes (the vasa deferentia, *vd'*), with the vesiculæ seminales (*vs*), which discharge, by their small extremities, into the large mucous glands (*mg*), at whose junction originates the ductus ejaculatorius (*de*), terminating at *o*—the beginning of the true organ of generation, which, in the condition of repose, lies outside in, and so within the cavity of the body; while, in activity, it assumes the form given at E.

The testes are tender, white bodies, slightly flattened, and much smaller in the adult drone than the ovaries of the queen, to which they are homologous—*i.e.*, they are to the drone what the ovaries are to the queen. They lie within the abdomen, at its upper part, and on each side of the digestive organs. Spermatic tubes, or canals, to the number of about 300, which open upon the vas deferens, make up nearly the whole of their substance.

In the male chrysalis the testes are already not only existent, but of enormous size, equalling at this time, perhaps, the ovaries of the queen. They lie over the then blind intestine, toward the dorsal surface. Their canals are, at this time, filled with spermatic vesicles (*sv*, B, Fig. 41), and with filamentous spermatozoa, many of which are endowed with a lively movement. (We must somewhat anticipate, by saying

that these active threads are, really, the instruments of impregnation, and have to be transferred to the female.) As they lie, by tens of thousands, in parallel lines, undulating rhythmically through their whole length, they have, under the microscope, a most extraordinary appearance, which has been likened to a field of barley oscillating under a gentle breeze. When the drone quits the cell, the testes are still very large, and extremely active, and but few spermatozoa have been transferred to that part of the body from which they can be discharged, so that the drone is not at this time, nor is he for several subsequent days, fully fit to accomplish the purpose of his existence. But the virile threads, maturing rapidly, keep passing from the testes to the *vesiculæ seminales*, which become now completely charged with them. It is by opening the *vesiculæ* at this stage that spermatozoa are obtained in the best condition for the microscope. They are such wondrous objects that I will explain a method I have pursued most successfully in mounting them. Secure a drone (not newly-hatched), as he is perambulating the combs, open the body, remove the vesicula, break one end, and, with the forceps, apply, for a moment, the ruptured part to the surface of some glass covers upon which a small quantity of water has been placed (one vesicula will give a supply for a dozen slides); leave to dry, keeping from dust; warm in the flame of a spirit lamp to set the albumen, pour on each three or four drops of watery solution of Spiller's purple, and, after five minutes, wash, dry, and mount in Canada balsam. For critical examination with high powers,

spermatozoa should be mounted in glycerin. If staining be desired, a minute quantity of the purple added to the glycerin will accomplish it, as, in a few weeks, the spermatozoa will have absorbed every trace of the dye.

To return. The testes, although retaining partial activity, shrink and flatten as the drone reaches virile maturity. The mucous glands, secreting a slimy liquid, give to the separate spermatozoa some cohesive power, presently utilised. The spermatozoa, mingled with mucus, pass continually onwards, through the ductus ejaculatorius (*de*), into the bean, where a mysterious arrangement of the myriad threads occurs. They fill up the bean (*b*), and their mass is now denominated the spermatophore (seen lying under *ts* in the Figure). The ductus ejaculatorius has walls of great muscularity, and, in the act of mating, it is one of the main forces for putting the organ right side out, so that it becomes external to the body. The rounded little white, and somewhat fleshy, part, the bean (*b*), is united to two brown, crescent-shaped scales (*s*), and two triangular ones (*ts*), which are rudiments of the usual *armor copulatrix* of the *Hymenoptera*. The bean, and the remaining parts, from *o* to *m*, are surrounded by a membranous sheath, which remains intact after the expulsion mentioned above. The curious, bright brown ridges (*r*, *A*, and *r'*, *E*) hinder the withdrawing of the organ during coition, and aid in tearing it, according to rule, from the body of the male. Below the ridges are found two membranous sacs (*h*), which are always more or less filled with air, and have been called *pneumophyses* from this fact. In

repose these parts are bent and flattened, but when swollen they become hard and resistant, and take the form of divergent horns, which, as they expand in undergoing eversion, pass into and fill the bursa copulatrix of the queen—a recess on both sides of the vagina. If a drone (by preference, one caught as he settles on the alighting-board, from his quest on a fine summer day) be pressed between the fingers, from the thorax towards the end of the abdomen, his organs will be expelled, because the air sacs are full, and the whole animal in an excited condition. They will then, wholly or in part, assume the form shown at E, and may be dried, attached to the body, and kept for subsequent study. This experiment will enable us to understand the manner and order of the extraordinary changes that occur during coition. Under excitement, indeed, the extrusion frequently happens to the drone without any mechanical squeezing, a sudden decapitation not unusually occasioning it; and dead drones, with the organs external, may constantly be found about the apiary in the summer.

The spermatophore, ovoid in form, gives, by interior pressure, a bulbous shape to the upper part of the organ, which lies loosely within its sheath in the cavity of the abdomen, and adherent to the body at the edges of the sexual orifice only. If a glove have one of its fingers turned outside in, the latter being then filled with some semi-fluid matter, such as paste, it may illustrate the action at the time of the *accouplement*. The junction of the finger with the hand of the glove will represent *m*, A (Fig. 41),

the top of the finger the termination of the organ, σ , while the hand will be equivalent to the abdomen. If we blow violently into the glove, the finger will be extruded. But, to complete the illustration, the top of the finger should have an aperture similar to that at σ , by which the spermatozoa composing the spermatophore enter the bean. Repeating our experiment, the glove finger is not only extruded, but, as the extrusion is completed, the paste will be forcibly driven from its end.

The drone is very blunt at the termination of the abdomen, which turns somewhat under, so that the orifice is inferior. By well-regulated finger pressure upon the internal organs, commencing from the thorax, as previously mentioned, the orifice becomes more external, and, rolling out its internal wall, we first bring into view a greyish-brown, rounded part, the thickly-set, short spines, with curved points, covering it, clearly indicating its purpose. This is the "*masque*" of Réaumur (m' , E), which is simply the side view of which m , A, is the front. The pneumophyses (h') now present themselves, unroll, fill out with air, in bubbles, as represented, and take up a position (h') in advance of the "*masque*." The process continues as the pressure is increased, the fan-shaped appendage (f') now, like the last, turning absolutely, so that that which was the inside becomes the outside; and here, in nineteen cases out of twenty, the extravasation ceases. But in coition it is continued until the bean has become external to the drone, so that the spermatophore is lodged in the common oviduct (*co.d*, Fig. 42) of the queen. Let us now endeavour

to understand why finger pressure is usually unsuccessful in completing the remarkable process. The theory I suggest appears to me almost conclusive. The force which determines the change now under consideration is derived from the pressure the drone brings to bear upon the sexual apparatus, by a violent contraction of the abdominal muscles. Suppose this equal to 1lb. on the square inch, the contents of the ductus ejaculatorius, with every internal part, will be subjected to the same; but the muscles of the duct itself also contract with great energy and power, and, if equal in force to those of the abdomen, add another 1lb. pressure to the mixed mucus and spermatozoa within. The first mechanical force tends to drive the organ to the outside of the abdomen; but the second drives the spermatophore backwards, so that it is blown out like the pellet from a popgun, and then the aperture (ϕ) allows to pass some of the fluid from the ductus ejaculatorius, just as air escapes from the glove finger after the removal of the supposed mass of paste. Finger pressure fails because, although it can fully substitute the muscular energy of the abdomen, it cannot give any equivalent for the driving energy of the ductus ejaculatorius; but a little practice will overcome the difficulty, carefully continuing to drive the body contents forward being all that is necessary. When the last step is reached, a sudden explosive effect is produced, which will soil the clothing with flying droplets, unless care be taken.

The queen has no pressure within her abdomen, because she has now no gravid ovaries, and her air sacs are small, so that no opposition is offered to

the large mass of material to be transferred. What has been said upon Flight will more fully explain the case of the drone. The more distended the stomach (and the male always leaves the hive, on a love tour, loaded with honey) the more easily is the extrusion accomplished; but it would be utterly impossible unless the air sacs were stretched to their utmost capacity; so that coition is impracticable on foot. This explains why Huber never saw the *accouplement* between drones and a virgin queen shut together in a box, and why fertilisation in confinement—the dream of enthusiastic apiarists—has, to this hour, presented difficulties which would appear to be practically unconquerable. The natural laws against interbreeding shows this fact to be beautiful in its fitness. The queen is not importuned in the hive, and, when she flies abroad, the fleetest drone is more likely to succeed in his addresses than another, and thus he impresses upon posterity some part of his own superior activity and energy. The slow and weak in the race die without heirs, so that the survival of the fittest is not an accident, but a predetermination. In previous chapters we have considered his highly developed eyes, meeting at the vertex of his head; his multitudinous smell hollows, and his strong and large wings, the advantage of which now appears in a clearer light; his quickness in discovering a mate, whose neighbourhood is to him filled with irresistible odours, and his ability in keeping her in view during pursuit, are no less helpful to his purpose than fleetness on the wing; but the success of his suit brings the close of his career, for, quickly after

the deliverance of the spermatophore, leaving his abdomen surprisingly flattened and reduced, the organ is torn from his body, in a manner respecting which we have nothing better than hypothesis (or reputed observation, which can hardly be regarded as either conclusive or satisfactory). His death follows, but certainly not so instantaneously as some have asserted, and the queen returns to the hive, bearing at the extremity of her abdomen the marks of her impregnation, as protruding shreds of torn membrane, to be dragged away, dried and shrivelled, during the next twenty-four hours. She is now more than a female; she has within herself the potency of the two sexes, and, during the term of her whole natural existence, she will be able to determine and accomplish, in time and number, within her own body, the mystical union of male and female elements which constitutes the act of fertilisation.

The powers of the drone just described are, almost with certainty, not alone true for those brought up in the normal cells of their sex, the issue of a fertilised mother, but for all indifferently. Hereafter we shall more fully explain that the egg yielding the drone is unfertilised, so that those born of mothers that have never mated (drone breeders) are as perfectly developed and as fully virile as the others. Dwarf drones also, raised accidentally in worker cells, or those from the eggs of so-called fertile workers, or workers which, although incapable of impregnation, have yet commenced ovipositing, seem not one whit behind the rest. Leuckart has claimed to have well established this fact for some drones produced by an

Italian fertile worker, and which gave, with a black queen, some workers of the mixed race. In such cases as these, where so much is beyond the reach of actual observation, it is best to cautiously abstain from dogmatising, but the spermatozoa which these drones contain I have found perfectly indistinguishable, microscopically, from those in the normally produced insect.

The statement that fertilisation differentiates the sex in bees—a matter into which we shall enter fully hereafter—introduces some of those curious freaks in which the parts common to the two sexes are distributed, in ludicrous confusion, to one individual, to which the name hermaphrodite is alone applicable. A few strange cases have occurred in my own apiary; but the most remarkable were sent me through the kindness of Mr. Thompson, of Blantyre, his knowledge of the typical forms enabling him to detect the abnormal ones, which, no doubt, exist more commonly than some suppose, but pass unnoticed. An account, in few words, of three of these will suffice. No. 1: Head—worker; perfect worker eyes, antennæ, and tongue; Thorax—worker, except targum (back plate), which is that of drone; legs all worker but one—the right of the third pair; Abdomen—completely drone in outline; seven segments, sexual organ male, but actually accompanied by a rudimentary sting and small poison bag; sting partly developed on one side, and aborted on the other. Had died with the sexual organs protruded. No. 2: Head—partly worker; drone tongue; one compound eye large, and rising nearly to vertex, other that of worker, ocelli set far back;

Thorax—worker, but too wide to be normal; small and imperfect wings; very narrow plantæ on hind legs, otherwise like those of worker; Abdomen—flat and wide, carrying imperfect drone organs. No. 3: Head—drone, short tongue, and eyes meeting at vertex; Thorax—wide, but of worker above; first pair of legs those of drone, the rest worker; Abdomen—like that of drone, but with only six rings. Some such bees as these *alive* is a desideratum, as their internal structure would aid in the solution of some questions of homology and development.

Since the queen mates but once, it follows that only an inconsiderable fraction of the drones raised really complete the intended cycle of their being. Colonies of bees, left entirely to their own devices, will often produce in the spring from six to eight thousand of these males, which consume much and yield nothing, when perhaps but one, or at most two, queens raised in that colony will need fertilising. These facts, incorrectly interpreted, in the absence of a knowledge of the beautiful laws by which these matters are regulated, have led to the supposition that some other office was fulfilled by the drone, he, it has been said, being especially intended to maintain the temperature of the stock after the swarm has departed. It is quite fatal to this baseless theory, that drones principally congregate on the honey, and not on the brood cells, and that they often, in great part, leave with the swarm. But, above all that, when the queen has been fertilised, they are frequently killed as useless incumbrances, no longer to be tolerated, and the cooler the weather, as it slackens

the honey yield, the more certain is their destruction. Mr. Haviland* has, in a very thoughtful and well-argued paper, treated this matter. He points out that, "If hive bees were in the habit of producing, as most solitary bees do, males not greatly exceeding in number the females, then the queen of that colony which produced most drones and fewest swarms would leave most descendants, for a queen may leave descendants by her sons, or by any daughter who is provided with a swarm of workers; and it must cost the colony far less to rear a drone than a queen, and all the thousands of workers who must accompany her if she is to have a chance of leaving descendants. Hence, indeed, until the chance that a drone would have of leaving descendants is far less than that a queen would have, the excessive drone-producing colonies would naturally be selected, and the selection of variations favourable to the colony might conquer those favourable to the species." Paraphrasing, in part, Mr. Haviland's words, it is clear that the mating queens of an apiary are more likely to meet drones from those colonies raising them in vast numbers than from those furnishing few. The instinct, then, of heavy drone-production is carried into the greater number of new colonies, an effect to be intensified at each swarming epoch, so that there is a perpetual tendency to increase the evil. It must, however, also be argued, that a large production of drones is, in one respect, favourable to the species, in that it minimises the risk of the young queen in seeking fertilisation; for, the greater the certainty and prompti-

* "The Social Instincts of Bees, their Origin and Natural Selection," 1882.

tude of a *rencontre*, the fewer excursions with the object of mating will be necessary. The natural check is the loss which the horde of consumers entails, causing the colonies in which the instinct is most highly developed to die out in times of scarcity, or during the winter.

It is interesting to note, that the very causes which have led to a development of drones disadvantageous to the species, has also produced an instinct for their destruction so soon as any chance of further normal need of fertilisation has ceased for the season. These pleasure-loving and lazy creatures thus come under a general proscription when honey, or, rather, food, is no longer yielded abundantly, for their evil day may be put off indefinitely, by giving their stock a constant supply; and even sometimes when the edict has gone forth for their destruction, a favourable turn in the weather, increasing the honey yield, will lead to their re-admission. But no sooner does income fall below expenditure, than their nursing sisters turn their executioners, usually by dragging them from the hive, biting at the insertion of the wing. The drones, strong for their especial work, are, after all, as tender as they are defenceless, and but little exposure and abstinence is required to terminate their being. So thorough is the war of extermination, that no age is spared; even drone eggs are devoured, the larvæ have their juices sucked, and their "remains" carried out: a fate in which the chrysalids are made to take part, the maxim for the moment being, "He that will not work, neither shall he eat."

CHAPTER XIV.

QUEEN ORGANS AND DEVELOPMENT.

Parallelisms between Queen and Drone—Both Domestically Helpless—Ovaries and Oviducts—Homologies—Spermatheca: Microscopic Examination of—Leidy's and Leuckart's Observations—Movements of Spermatozoa—Parthenogenesis: Curious Examples of—When the Queen Mates—Exceptional Cases—Drone-breeding Queens—Drones have no Fathers—Dsierzon's Experience—Fertile Workers—Inevitable Conclusion—Appendicular Gland: Its Homologue—Spermathecal Valve: Its Muscular System—Nameless Gland—Number of Spermatozoa—Old Queens Breed Drones only—Number of Fertilisations required—Wasps—Fertilising Pouch—Egg Structure—Micropyle: Uses of; and Origin—Ovaries of Workers: Barren and Fertile—Siebold's Examinations—Oviduct: Structure of—Prolonged Vitality of Spermatozoa—Results of Freezing Queens—Paralysis producing Drone-breeders—False Theories—Worker Egg a Misnomer—Development of Larva—Queen Cocoon and Exuvium.

THE surprising sexual development of the drone, and his extreme domestic helplessness, are paralleled

by the queen (Fig. 5), which, apart from her faculty of reproduction, is almost in every point the inferior of the worker (see page 55). We have learnt that both she and her partner have relatively small brain de-



FIG. 42.—OVARIES OF QUEEN, &C.

A, Abdomen of Queen, Under Side (Magnified Eight times)—P, Petiole; O, O, Ovaries; *hs*, Position Filled by Honey Sac; *ds*, Position through which Digestive System Passes; *od*, Oviduct; *co.d*, Common Oviduct; E, Egg-passing Oviduct; *s*, Spermatheca; *i*, Intestine; *pb*, Poison Bag; *p.g.*, Poison Gland; *st*, Sting; *p*, Palpi. B, Rudimentary Ovaries of Ordinary Worker—*sp*, Rudimentary Spermatheca. C, Partially Developed Ovaries of Fertile Worker—*sp*, Rudimentary Spermatheca.

velopment, and that the tongue of each is so short as to be unfit to gather honey; that their jaws are not suited to comb-building, and that neither has

wax glands; that the eyes of the queen are smaller and less prominent than the worker's, and her antennæ inferior, both in size and organisation. Her legs, though stronger, are less perfect, having neither pollen baskets nor pollen brushes; while the webbed hairs of the worker's thorax—effective instruments in food collection—she does not possess; her wings are less developed, and her sting likely to be rendered useless by atrophy and inspissation of venom; her digestive system is less complete, and her gland structures relatively defective, or wanting. Under the social instinct, she, like the drone, has been developed in one direction only; but here her faculties are more extraordinary than any to be found outside the order *Hymenoptera*.

If her abdomen be cut open down the sides by fine scissors, and the first three ventral plates and the chyle stomach removed, we discover two very large organs (O, O, Fig. 42), filling nearly the whole of the inclosed space, which corresponds exactly to that occupied by the testes in the drone. These are the ovaries, and consist each of from 100 to 150 blind tubes, lying side by side, and gathered into two consistent, conoid bundles, by countless small tracheæ, which act as connective tissue. The ovarian tubes are, at the upper end, very small, and here each egg is represented by an initial cell (the germ cell), which passes on during its development, receiving first its vitellus, or yolk, and finally being coated by the chorion, or outer skin (B and C, Fig. 46). It then continues moving downwards, as room is made for it by the escape of the mature eggs at the lower, wider end.

Egg germs are far later in making their appearance in the queen than are the spermatozoa in the drone, the former being invisible up to the time of the hatching of the queen nymph, whose ovarian tubes then are filled with pellucid globules, resembling those that *precede* the appearance of the seminal filaments in the drone testis. The eggs are of a pearly-white colour, and, during the time that queens are actively ovipositing, more than a dozen, in various stages of maturity, may be found in a single ovarian tube, or follicle, standing end to end, like the beads of a necklace. Of these, at times of activity, many will be ready for deposition; but, in winter, the number in progress will be reduced to one-half, or less, while scarcely any in a perfected condition exist. Each tube emerges into the oviduct (*od*), the commencement of which is formed by the opened-out walls of those on the outside of the ovary. The inner tubes unite together at their lower edges, and so complete the cover of the oviduct above, forming beneath them a funnel-shaped cavity (the ventricle of the oviduct), into which each egg first enters in its passage from the tube in which it had been matured. The delivery pipes of these funnel-shaped hollows (the oviducts), uniting to form the common oviduct (*co.d*), are really very highly organised channels, possessed of curious powers of the greatest moment.

The similarity between the drone and queen must here be remarked, the testes and vasa deferentia (Fig. 41) bearing, both in structure and position, a great resemblance to the ovaries and oviducts of the queen, these parts being, really, respectively the

homologues of one another, as are also the germ cell (initial egg) of the ovary, and the sperm cell (spermatozoon) formed in the testis. The egg, as laid, contains not only the germ cell, and possibly the sperm cell—the male and female elements for the production of a new individual—but also a store of food (food-yolk), making up its mass, and supplying material for the development of the embryo, until it is capable of absorbing nutrition by the processes of ordinary digestion. We noticed, in the last chapter, that the spermatozoa of the drone, as developed, passed on to a store-chamber (the vesicula seminalis), where these sperm cells awaited utilisation. The homologue of the vesicula is clearly a globular pouch in the queen (the spermatheca, *s*, Fig. 42, and Fig. 43), which receives and becomes the depository of the millions of spermatozoa ejaculated during the marital flight. Again, at the time of mating, the spermatozoa require a medium in which they may be floated into their proper destination, and, to supply this, the mucous gland (*mg*, Fig. 41) is provided; it is into this that the vesicula seminalis opens, and, during ejaculation (see page 205), the mucous secretion and the spermatozoa are sent forward together. The mucous gland has also its representative, or homologue, in the queen, in the appendicular gland (Fig. 44) of the spermatheca.

To return to the queen. Near the commencement of the common oviduct (*co.d*, Fig. 41), which is fastened, by complicated attachments, to the fifth abdominal ring, we find the before-mentioned globular body (*s*),

rather more than $\frac{1}{25}$ in. in diameter, glistening like burnished silver, because coated with the closest and most densely felted plexus of tracheæ with which I am acquainted. This spermatheca is in structural communication with the common oviduct, but the smallest roughness will break it from its attachment, and will frustrate any endeavour to discover how it is filled up and used. Should it, by accident, become detached, however, we may still study the exceedingly curious and complicated valvular appa-



FIG. 43.—SPERMATHECA (Magnified Forty times).

a, Space filled by Clear Fluid; *b*, Mass of Spermatozoa; *c*, Spermathecal Duct; *d, d*, Spermatozoa in Activity.

ratus with which it is furnished. Removing it to the stage of the dissecting microscope (see page 74), and surrounding it with dilute glycerin, we get glimpses of a contained membrane between the meshes of the investing tracheæ. So far as I know, those who have studied this matter have failed to discover that these tracheæ merely closely embrace the actual spermatheca, and that they in no instance enter its walls; but such is the fact, and, by very careful teasing and cutting with needle-knives, we may so separate the

multitudinous air tubes that they may be pulled off, as a rind from an orange. The sac itself (Fig. 43) is now seen to have beautifully transparent sides, giving faint indications of originating in coalescing cells, but having no discernible structure, except near its outlet, where it has an epithelial lining. Through its sides, if the queen is unimpregnated, we discern only a perfectly clear fluid.* But should the queen have recently mated, the whole interior is densely clouded and semi-opaque, since it is perfectly filled with spermatozoa, which are recognised at once as identical with those previously found in the drone, and from whom they have been received and packed by a process we can only understand hereafter; but, as older and yet older queens are operated upon, the spermatozoa decrease in number, but, instead of being generally diffused, are gathered into a tolerably compact mass, which lies in contact with the aperture (*c*, Fig. 43), the remainder of the sac being occupied with a transparent liquid, as in virgin queens. The countless multitude of spermatozoa is arranged in a definite manner, resembling a collection of long tresses (*b*) combed out after recent plaiting, and as indicated in the Figure. The extremities of the motile threads point towards the aperture, while, from their upper surface, spermatozoa are observed to rise in different spots (*d, d*), like microscopic eels, long and thin, curling and twisting with much grace, as they hold on by their

* Langstroth, in notes at pages 126 and 213 of his book, tells us Leidy found a granular fluid, and Leuckart one that was clear. Leidy is certainly in error; while neither of these observers made, in any true sense, a dissection of the parts, since they merely crushed the spermatheca flat, and examined the escaping matter.

tails. After a few seconds, they lapse into quietude, to be, in turn, succeeded by others; and, in a warm room, this curious set of movements will be long continued, even though several hours have been occupied in dissecting the abdomen whence the spermatheca have been taken.

Gently squeezing the spermatheca shows, since no spermatozoa escape by the duct, that it is closed by a valve, whose structure we must, by-and-by, study. The pressure increased, the delicate bag at length bursts, and a true microscopical marvel awaits us. The spermatozoa escape in tufts, consisting of hundreds of thousands, each of which is wriggling to be free; and quickly they are widely spread, curling and uncurling with a peculiar snapping movement, and with an energy that baffles description. Their powers in a few minutes begin to wane; then, one after the other, they take a form closely resembling two 8's, one over the other, surrounded by a rather larger O (*a*, C, Fig. 41). When all have sunk to rest, this singular pattern, repeated with strange regularity, covers the field, though sometimes the threads take a wider outline, as the illustration makes clear. It remains to be seen by what means these spermatozoa are packed in the spermatheca after being received from the drone, and how they are transferred to the egg as required, and whether they are so transferred in all cases. But before considering the structures involved, it is well that we should direct our attention to the theory of parthenogenesis, or production by a virgin, which facts, observed half a century since, satisfactorily showed to exist both in wasps and bees; but the argument

remained entirely constructive in character, until I was fortunate enough to establish for it an anatomical basis,* which not only explains the facts, but the structures which make them possible.

Parthenogenesis, or reproduction without fecundation, by virgin and perfect females provided with ovaries and spermatheca, is no new fact in entomology. It received recognition at first in the earlier half of the eighteenth century, in the case of some virgin female silk moths, and afterwards in others of the *Bombycidae*, all of which produced eggs hatching out both sexes. Later, an incomplete parthenogenesis was observed in the *Psychidae* and some nearer relatives of the bee (the gall flies), the virgin females laying eggs yielding exclusively females (the less perfect form in these genera); the process being repeated, during twenty generations, without a single male individual presenting itself, or one case of impregnation having occurred. Indeed, amongst some moths, the male is at present altogether unknown. Nor have we at all exhausted our knowledge of these surprising variations from a rule formerly thought to permit of no exception; for, amongst other similar cases, in a species of *Cecidomyia*, a small insect, living, in the larval state, beneath the bark of trees, the larva is itself fertile, producing creatures in its own likeness, which at maturity tear open the side of the parent and escape, themselves to similarly give rise to another

* "The Apparatus for Differentiating the Sexes in Bees and Wasps. An Anatomical Investigation into the Structure of the Receptaculum Seminis and Adjacent Parts." F. R. Cheshire. *Journal Royal Microscopical Society*, February, 1885.

brood, until the close of the season, when true metamorphosis occurs, and the adult form of the insect makes its appearance.

And who, too, is unacquainted with the far too common, sexless, budding *Aphis*, passing through several generations, until perfect, sexual, wingless *Aphides* are brought into existence, upon which seems to be laid the task of continuing the race to the succeeding year. And, leaving the domain of insects, we meet with no less curious instances. Amongst the lowly Rotifers, by example, females are generated by virgins, and males by mated individuals. Nor is parthenogenesis unknown to the world of plants. Dr. Asa Gray gives, as an example, *Cælebogyne*, respecting which he says: "Parthenogenesis is thus confirmed, and is known to occur in most polyembryony."*

But it may be argued, that the queen bee is only capable of filling her office as a mated insect, and that, consequently, these illustrations do not apply. In the majority of cases, this is so. Ordinarily, for the first six days following her escape from the queen cell, she manifests no disposition to make an excursion abroad, although numerous drones may be without, floating in the bright sunshine; and even after this period, when the elements are unfavourable, through chilly winds or falling rain, or in the morning or evening, when drones are at home, she quietly stays within; but, at the age named above, during the three hours or so which follow midday, when the weather does not forbid, and when the drones are executing their sonorous

* "Structural Botany," page 285. Macmillan and Co., 1880.

evolutions, the young queen, if prevented from leaving, becomes greatly agitated, seeking an exit at every point, until the drones are once more at home. If at liberty, she flies daily with increased anxiety, until the object explained in the last chapter has been realised, when, about forty-eight hours after, she deposits her first eggs, which invariably produce workers.

But exceptional cases often arise, and it is in harmony with facts such as those before given, and which have long been known, that a queen, or mother-bee, is not doomed to *total* sterility if raised at a part of the year when drones do not exist, but that she, although later than at the normal period, begins to deposit eggs, which, however, are in no instance converted into workers, but invariably produce drones, which must, of course, in her case at least, be generated parthenogenetically. Queens having defective wings, and so incapable of mating, are also invariably drone-breeders. Similarly, if a queen of the Italian race (*Apis Ligustica*), which has consorted with an Italian drone, be placed in a hive containing English bees (*Apis Mellifica*) only, and which is itself located in a neighbourhood where Italians are unknown, all her progeny, both workers and drones, will, to the end of her life, continue pure, carrying their characteristic yellow abdominal bands, and a thousand other minor distinctive peculiarities; but should she leave with a swarm, or die, the workers will raise a successor from one of her eggs. The new queen of unmixed blood must of necessity mate with an English drone

(allowing, for the sake of the argument, that her mother has produced none), and, as a consequence, the workers, her progeny, will partake of the qualities of the two races, exhibiting among themselves those variations for which hybrids are remarkable. But her drones, on the contrary, will still be absolutely Italian, again showing that, although their mother was impregnated, her impregnation had in no way influenced *their* generation, or that they, as before, had a mother but no father; so that the eggs whence they came had in some way escaped fertilisation. Almost all apiculturists have had abundant evidence of a kindred kind; but it was the introduction of *Apis Ligustica* into Silesia, in 1853, which gave Dzierzon the first incontestable proof of the parthenogenetic production of the drone. Yet further evidence is given by the occasional appearance of fertile workers, whose existence has been previously referred to, which, from their anatomical structure, are incapable of coition. These, nevertheless, deposit eggs which, for reasons now evident, produce drones only. The conclusion cannot be evaded, that, in the genus *Apis*, where the least-developed form would appear to be the drone, the egg is already sufficiently vitalised for giving him birth when it has reached maturity in the ovary, but it requires the concurrence of the male spermatozoa to produce the female, the most highly endowed and organised of the sexes amongst the *Hymenoptera*. Our normally mated queen, then, according to season and the necessity of the colony, deposits eggs, either in the smaller cells, yielding workers, or in the

larger, furnishing drones, because she possesses the extraordinary faculty of giving at will, or withholding, spermatozoa from the egg about to be deposited. Let us return to the study of her anatomy, for the purpose of unravelling the mystery of the mechanism by which this is accomplished.

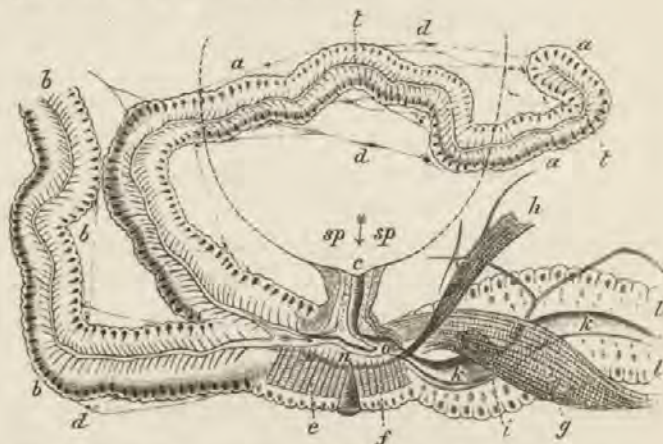


FIG. 44.—PART OF SPERMATHECA AND VALVE, WITH APPENDICULAR GLAND
(Magnified Sixty times).

sp, Spermatheca deprived of Tracheal Coat; *c*, duct; *a, a, a, b, b, b*, Right and Left Branches of Appendicular Gland; *t, t*, Duct of Same; *d, d, d*, Nerve Connections; *c* and *f*, Sphincter Muscles; *g*, Muscle to Extend Valvular Opening; *h*, Muscle for Closing Valvular Opening; *i*, Ganglion Lying Under Muscle; *k, k*, Duct for Spermatozoa; *l, l*, Glandular Structure surrounding Duct.

Taking a complete spermatheca, we turn it until it presents an outline not unlike the back of a man's head, carrying a pair of large and prominent ears. The latter are the upper ends of the right and left branches of a gland (*a, a, a, b, b, b*, Fig. 44, and *ag*, Fig. 45), which are of considerable length, and about $\frac{1}{12}$ in. in diameter, and which are held in

position by receiving very numerous twigs from the tracheal net (*sp*, Fig. 45) inclosing the spermatheca. These branches pass down the opposite sides of the sac, and unite near to its aperture (*c*, Fig. 44). The whole gland consists of nucleated cells, surrounding a common duct (*t, t*), which runs from end to end, and enlarges somewhat during its course. Its type is very distinctly intracellular (page 77), and the different ductlets, many thousands in number, leading from the very numerous independent cells, are indicated in the Figure. Its activity and importance are further shown by the multitudinous nerve twigs and cells (*d, d, d*), giving it general energy, and bringing its various parts into relation. The name "appendicular" appears to me ill-chosen, since there is every reason to regard this gland as the homologue of the mucous gland of the drone; "mucous gland of the female" would have been, therefore, more expressive. New names are often confusing, so the old one will be retained during the description. The spermathecal duct (*c*), which is short, stiff, and slightly ribbed, points towards, but does not immediately enter, the duct of the appendicular gland. I find the disposition of the whole to be that of a valve, to which, and to these ducts, are attached five main muscles, two being sphincters (indicated at *e* and *f*). The latter extend upwards farther than represented, their continuation being omitted lest they should obscure the structure of the valve before and behind which they actually pass. These sphincters are the instruments for respectively and independently closing the appendicular-gland and spermathecal ducts. They

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are separated by an intervening wedge-shaped disc, so that they lie towards each other, at an angle of from 30° to 60° , and may be beautifully shown by polarised light. An indurated integument, probably a chitinous plate (*n*), is pushed towards the spermathecal duct, by the contraction of its proper sphincter (*e*), and in this work it is aided by the muscle *h*, which is one of two, whose tendinous extension is about $\frac{1}{1000}$ in. in diameter, or $\frac{1}{24}$ th the thickness of a human hair. These muscles would, no doubt, all remain tense while the insect was in a condition of repose; but should she be engaged in ovipositing, and spermatozoa be required for fertilisation, the muscle *g*, by contraction, would lift the plate lying above and between *o* and *k*, to which, by a complex tendon, it is attached. Into the cavity (*v*) thus opened, spermatozoa would pass; the two sphincters at the same moment relaxing, an outflow of glandular secretion, as indicated by the arrow, would be ready to sweep the spermatozoa towards their destination in the common oviduct, and all would be driven on by the appendicular sphincter *e* first contracting, followed in order by the second sphincter (*f*), and muscle marked *h*, when both ducts would be closed, and the repose condition re-established.

A most remarkable adaptation here arises. The spermatozoa yielded by the drone are, probably, not usually more than 4,000,000 in number. It is, of course, extremely difficult to make a calculation; the very highest estimate, I have ever reached is 12,000,000; Leuckart states that the spermatheca may

contain 25,000,000 of spermatozoa. While not denying possibility to his estimate, I certainly think it far too high. Whichever sum be accepted as the true one, it is demonstrable, that economy in the distribution of these fertilising threads is of the highest possible moment, for, should they be shot forth haphazard, they would be exhausted long before the queen's death, when she would be, of course, reduced to the condition of a queen that had never mated, and so become, like such, a drone-breeder: a circumstance by no means uncommon—presenting itself, indeed, quite frequently where, under careless management, queens are allowed to fade out instead of being displaced. They may then, in the absence of accident, attain the ripe old age of four, or even five, years. Many of these ancient dames—discarded because they no longer yielded workers, or only a few, amidst many drones, and these produced in worker cells—have been sent to me for dissection, and I have invariably found the spermatheca quite denuded of its spermatozoa, or only containing such a miserable residue as to clearly show that the eggs could, at the best, be but occasionally fertilised. The economy we see to be so essential is secured as follows: The duct (*k, k*) through which the spermatozoa pass, as extruded in detachments from the spermatheca, I find to be the centre of another gland (*l, l*), which seems to have escaped the attention of previous observers. This gland we may fairly infer to be excited to secretion by the presence of the spermatozoa, just as food excites our salivary glands to the secretion of saliva, and the stomach to the secretion of gastric

juice. Spermatozoa, thickly present, will cause the addition of large quantities of fluid, more widely separating them. Their absence (for this gland is most richly provided with nerve twigs, which send numerous loops to the muscles previously described, and to the ganglion, *i*, lying under the muscle, *g*, and placed just over *k* in the Figure) will yield the action which will send a new contingent forward as I have described, and so they come to be paid out with some regularity. The necessity for this regularity will be better appreciated if we remember that a prolific queen will lay, during her life, 1,500,000* eggs (see page 83)—a number so vast that the eggs, lying in contact, end to end, would stretch about one and three-quarter miles. Deducting a few thousand for drones (for the production of which spermatozoa are not needed), the remainder would each require an independent fertilisation, and, for this work, possibly, 4,000,000 spermatozoa, or even less, may be at command. In this connection, it is most interesting to note that the spermatozoa, in the different genera and species, stand in beautiful relation to the number of eggs deposited by the fertile female. In the queen wasp, by example, the fecundity is much less, happily, than in the honey bee, and so the spermatheca is considerably smaller, the capacity of that of the former insect being only about one-fortieth of that of the latter, the spermatozoa being nearly of the same size. The organs of the *male* wasp are correspondingly reduced.

* This number is much beyond an average; but it certainly has been reached, if not exceeded.

I have found the channel *k, k*, to contain a membrane of extreme tenuity, only made visible with difficulty, and this is remarkably convoluted, after the manner of the epididymis of higher animals. Tracing the channel onwards till it perforates the side of the common oviduct turned from us in Fig. 42, or towards us in Fig. 45, a bifurcation is detected, with one channel, apparently wide and indefinite, which is

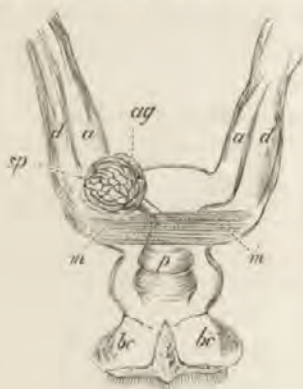


FIG. 45.—PASSAGE CONNECTING OVIDUCTS WITH THE EXTERIOR OF THE BODY (Magnified Ten times).

sp, Spermatheca; *ag*, Appendicular Gland; *a*, Upper, and *d*, Lower Path for Eggs; *bc*, Bursa Copulatrix; *p*, Fertilising Pouch; *m*, *m'*, Muscles for Contracting Side Path.

quickly lost by its becoming confluent with the lower part of the oviduct, whilst the other enters a central and curiously-folded apparatus (*p*, Fig. 45), which, for a reason to be presently given, I shall denominate the "fertilising pouch." I have strong reasons for supposing that the path from the bursa copulatrix (*bc*)—into which the male organs are locked by the horned pneumophyses (see page 203)—

and from the parts of the oviduct above it, through the deeply-folded pouch (*p*) to the spermatheca, is so involved, that it would not be possible for the spermatozoa, by following it, to enter the latter when given up by the drone; but that, in the early life of the queen, the second wider and straighter channel to which I have referred, is fully open, and by *it* the spermatozoa, with their inscrutable power of self-direction, pass upwards, avoiding the mazes of the fertilising pouch, and packing themselves for future use pretty much as they were arranged in the spermatophore in the drone's body. The queen, if still unmated at four or five weeks old, becomes incapable of copulation, or, at least, she evinces no desire for it, which fact possibly marks the time when this lower passage closes, such closure, in a mated queen, forcing the spermatozoa, in *descending*, to take their way by the fertilising pouch.

If a central comb be lifted from a hive during the summer months, eggs in number will be discovered. If one of these be removed from either a worker or a drone cell, by means of the wetted point of a camel-hair pencil (for they are deposited with a secretion covering them, which causes them to adhere by the end, as at A, Fig. 46), its surface will be found, if examined microscopically, to be covered by a beautifully reticulated membrane (the chorion, B and C), almost as though a tiny pearl had been covered with what the ladies call blonde, many hundreds of the meshes of which are required to coat it completely. Arranging the egg so that we get a view of the larger end (D)—for which nothing excels a $\frac{1}{2}$ in. objective

and Lieberkühn—we find the netting disposed in a radiating pattern, reminding one of the cordage over a balloon, which leads up to the strong ring at top. In the centre lies a single aperture (the micropyle) marking the point for the insertion of the funiculus, by which the egg was attached during its growth, and from which it separated itself when sufficiently matured. The minuteness of the opening does not prevent its being continued through the underlying

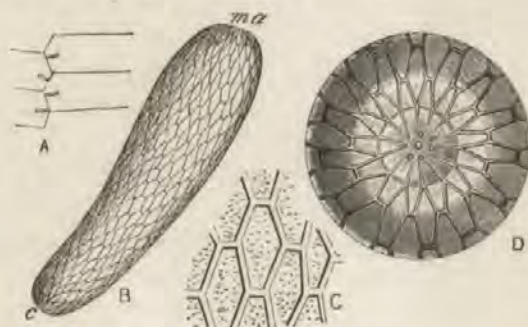


FIG. 46.—BEE-EGG AND DETAILS.

A, Position of Eggs at Base of Cells (Natural Size). B, Egg (Magnified Twenty-five times), showing Reticulated Chorion—*c*, Base attached to Cell Bottom; *ma*, Micropylar Aperture. C, Chorion (Magnified 200 times). D, Micropylar Aperture (Magnified 100 times).

egg membranes, and giving an opportunity of entrance to the spermatozoon, whose rhythmic movements, as though guided by intelligence, conduct it to the micropyle when the egg passes within the fertilising pouch, on its road towards being laid in a worker cell. The wondrous thread enters, coalesces with the germ, brings about fertilisation, and effects the resulting sex, as previously recited facts force us to believe. The egg so impregnated yields a female,

which will possess qualities both of father and mother; so that the tiny spermatozoon not only differentiates the entire creature, but communicates, unerringly, differences of species, or even mere variety. The spermatozoa from Cyprian, Carniolian, Italian, and English bees are to the most refined microscopical examination identical, and yet they contain differences which determine almost countless variations in form, colour, size, instinct, capability, and temper. In 1884 I made the extremely interesting discovery, that spermatozoa, when within the spermatheca, are subject to disease (*see* Diseases), and, in one instance, in which hermaphrodite (page 208) bees occurred, this disease obtained in the queen. Examples being so sparse, and the difficulties of examination so great, it is not likely that this fact will lead up to any generalisation; but it is most tempting to a spirit of speculation. If a spermatozoon converts that which would, in its absence, have been a male, into a female, may not a defective spermatozoon only in part produce the change, so that a mixed gender results? So far as we know, it is certainly in agreement with the evidence to admit the possibility.

That the spermatozoon enters the egg is certain, for it may be found, if the latter be carefully examined immediately after deposition. Siebold,* by crushing eggs which had immediately before been deposited in worker cells, was the first to discover

* Siebold "On True Parthenogenesis," p. 85 *et seq.*, and "Parthénogénèse chez les Insectes" (*Annales des Sciences Naturelles*, 4^{me} Série, 1856, vol. vi.).

the spermatozoa within. In some instances, he thought he saw as many as three that had passed the micropyle; but I cannot forbear expressing the opinion that possibly, or, rather, probably, Siebold has been in error here, since there is good reason for imagining that *one* completes the process of fertilisation. Positiveness would be much out of place; the whole investigation is so extremely exacting, and needs, for its successful prosecution, the concurrence of so many favourable conditions, that errors can hardly be avoided; the remarkable length of the body of the spermatozoon—about $\frac{1}{100}$ th of an inch, which is more than 300 times its greatest width—necessitates many convolutions, and would make misconception easy. Whether we have seen only one or more, may, for the moment, rest; but the interesting point lies in this, that the most careful examinations made by Siebold, and which I have confirmed by prolonged observations, show that no trace of a spermatozoon is found either within or upon the eggs laid by a fertile mother in drone cells.

Dr. Donhoff claims a curious corroboration by artificially impregnating, in 1855, an egg laid in a drone cell, by placing upon it a little diluted fluid from a drone testis, and transferring it to a worker cell. Others have failed in this experiment, but the argument for the parthenogenetic production of drones can well afford to do without the evidence it would supply, even if repeated by many observers.

The head (*h*, C, Fig. 41) of the fertilising filament is very narrow, that the micropylar aperture may be passed, but, to effect this, time must be occupied;

and how is this given? My previous explanations have made evident that the spermatozoa glide, not into a plain tubular cavity to meet the descending egg, but into a pouch contrived of curiously formed folds of the lining membrane of the common oviduct, and which, if stained with micro-carminé, takes up picric acid and becomes yellower than the oviduct proper, whilst its surface is dotted over with linear patches of setæ (or bristles), from two to six in a patch, and from $\frac{1}{10000}$ in. to $\frac{1}{8000}$ in. in length. Its structure is particularly difficult to examine, but it has three main cross duplicatures (*p*, Fig. 45) of an extremely attenuated membrane, which give to it somewhat the form of three joints of a lobster's tail, while it is only slightly wider than the diameter of the egg; and I have little doubt that here the latter is delayed when a female is to be produced, and brought into contact with spermatozoa delivered into the right position by the channel *k*, *k* (Fig. 44), whilst the eggs from which drones are evolved are carried down the path (*d*, Fig. 45) by the side of the pouch to the termination of the duct, and so escape all contact with the fertilising threads.

The oviducts are highly organised, containing a most beautiful system of longitudinal and transverse muscular fibres, repletely provided with nerve twigs, evidently giving to the oviducts the most complete control of the eggs which are to pass through them, while they are not without strong indications of two specialised paths (*b* and *c*), one towards the fertilising pouch and the other to its side. Near the junction of the oviducts, also, there are two thin

muscles (m , m' , Fig. 45), for which I can conceive of no purpose, unless it be to so reduce, by their contraction, the opening lying by the side of the fertilising pouch (p) that an egg could not, except they are relaxed, pass in this direction, and so escape fertilisation. That these parts have great regulating capability, and are not mere tubular conduits, is proved as much by their nerves as by their muscles. The last abdominal ganglion lies immediately beneath, and in contact with, the oviducts and spermatheca, and, from it, branches of nerves run in abundance into the oviducts, the spermathecal valve muscles, the sting, and their palpi; while small ganglia are distributed in profusion, a considerable one lying over the valve, and sending branches forward into the fertilising pouch. The manner in which the spermatozoon itself finds its way is utterly inscrutable. The fact of its continued vitality with no distinguishable change, either in size and form, or motile activity, during the whole of the queen's life, save from five to ten days, between which ages she usually mates, is most surprising. Constant nutrition and oxidation can alone be capable of sustaining it to the last in the freshness it had when first introduced to the spermatheca. Cold, however, kills it. Here Dzierzon's experiments have the deepest interest. He found that a queen which had been refrigerated for some time, although capable of revivification by warmth, never afterwards laid other than drone eggs, whilst before she had been a good producer of workers. Berlepsch placed three queens for thirty-six hours in an ice-house; two died, but

the third recovered, and laid abundantly, but drones only resulted. Similar experiments are also related by Langstroth, who adds that a short exposure to the intense cold of a mixture of ice and salt will answer every purpose. But, while the spermatozoa retain their energies—unless means be taken to destroy them—the queen, even when young, may become incapable of distributing them; and I have had, under the dissecting-knife, not less than four examples, that had been sent me as drone-breeders, but which I found to contain an abundant virile supply.

This condition may arise from the spermatozoa choking the duct, or from failure of the last ganglion, and Dr. Donhoff relates that he has produced it by simply gently pinching the terminal abdominal segment with a pair of forceps, after which the queen exhibited difficulty in laying, in consequence of the nerve injury.

The fecundation of the mother-bee was the subject of many false hypotheses before the facts were discovered. Swammerdam, observing a strong odour from the drone, supposed that this, permeating the body of the female, fertilised the eggs. The number of drones seemed to be explained by this *aura seminalis* theory, since a crowd would be required to produce the supposed emanation in intensity. Huber completely overturned this fancy, by placing the drones in a box pierced with holes, the vapours from which left the queen a drone-breeder. De Braw, observing little white masses at the bottom of the cells (really the last cast skin of the matured chrysalis), announced that drones fecundated the eggs

after they were laid, after the fashion of fishes. Huber, assured of the falsity of the idea, shut up all the drones of a hive, letting the mother fly, and found that she became fertile. We may smile at these ancient blunders, but really mistakes as grave and less excusable now obtain. It is even yet asserted by some, as the echo of a bold guess made long ago, by an American apiarist of just repute, though but little acquainted with scientific matters, that the narrower cells in which worker bees are raised, by pressing upon the abdomen of the queen, were the effective agents for forcing out the spermatozoa, and so causing the eggs to be fertilised. This notion, so repellent from its bald crudity, is shown to be utterly without foundation. Not only do queens lay worker eggs in cells whose sides are only commenced, so that pressure cannot be exerted, but experiment proves that the sex is determined according to the needs of the colony. Although the queen, if left in undisturbed possession of the combs the workers have built, will select the cells, and lay eggs appropriate to their sizes, she will, if provided with one kind only, deposit in part eggs of a sex opposite to that for which the cells are suitable; for, if a hive be filled with drone comb, workers will be raised in it. Fertilisation, now that we have so far conquered its *modus operandi*, is seen to be absolutely under control, and the outcome of a beautiful and marvellous mechanism.

But the egg, having been fertilised, may, according to subsequent treatment, yield either worker or queen. To be the latter is rarely its destiny, and so

it is commonly called a "worker egg," which is clearly inaccurate, and comes, like other mistakes of this kind, from terms being introduced and made current before the objects named are scientifically understood. The two essential forms of egg are the impregnated and unimpregnated, yielding the necessary concomitants of reproduction, the female and the male, the queen and the drone; and from the former, as the social instinct has been developed, the

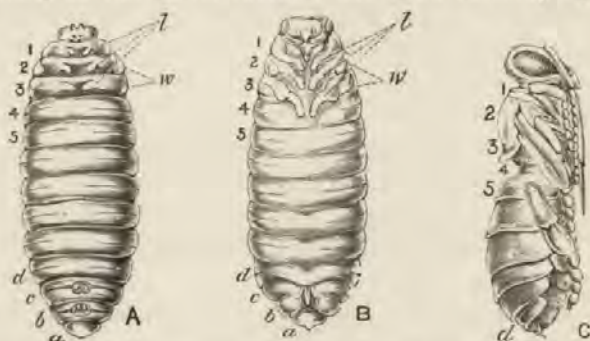


FIG. 47.—LARVA AND CHRYSALIS OF HIVE BEE (Magnified Four times).

A, Larva (full grown)—*a, b, c, d*, Terminal Segments; 1, 2, 3, 4, 5, Segments below Head; *l*, Budding Legs; *w*, Ditto Wings. B, Condition of Change intermediate between Larva and Chrysalis; Lettering as before. C, Chrysalis; Lettering as before.

worker has been produced. Labour has been divided. The queen has lost her domestic arts, which the worker possesses in a perfection never attained by the ancestral types; while the worker has lost her maternal functions, although she still possesses the needed organs in a rudimentary state. Ovaries she has, but so tiny as only to be found by elaborate dissection. They escaped altogether the vigilance and skill of both Swammerdam and Réaumur, and

are little better than an attenuated string of tubes, ten or twelve in number, and destitute of eggs or germs (B, Fig. 42), where, even yet, an indication of spermatheca (*sp*) remains. Although the cavity of the latter is almost entirely obliterated, the vestiges of the appendicular gland pass into its base after the manner of arrangement in the fertile mother. The vagina lies at the side of the intestinal opening, and is frequently imperforate, while the bursa copulatrix (*bc*, Fig. 45) does not exist, so that the reception of the male organ is impossible. Workers, like queens, pass through a very considerable range of variation, and an instance of worker copulation, which has been scientifically verified, is on record. Under excitement, and in the absence of a queen, the ovarian tubes will, in rare instances, extend, and eggs be laid, producing, as we now know, drones, the ovaries, when dissected out, presenting then the appearance of C, Fig. 42.

In previous chapters, we have traced the development of the larva within the egg, and have studied the remarkable transformations in the arrangement of the internal parts that occur during the chrysalis stage; and it seems fitting that we should now direct our attention to those previously omitted transformations which gradually change the egg, whose qualities we have just investigated, into the outline of queen, worker, or drone. The oviducts are provided with secretion cells, which coat the egg with an agglutinative body, so that, as it leaves the queen, it adheres by its smaller end, as before pointed out. It sustains its outstanding position for the first day, but then

gradually sinks. The chorion of the egg (C, Fig. 46) breaks, usually after three days (the time varies according to temperature), and a footless larva, with thirteen segments, exclusive of the head, alternately straightens and bends its body to free itself of the envelope. It is extremely curious that, before hatching, the larva presents rudimentary legs, which disappear—a fact which some have supposed to indicate (atavism) a reference to an ancestral type in which the larva bore feet; but this does not seem to be valid, for reasons which would encroach too much on our space. Towards the end of the larval period, the three segments following the head (1, 2, 3, A and B, Fig. 47) have little scales (*l*) beneath the skin on the ventral side, which are the beginnings of the legs, and which cannot be seen until the creature has been immersed in alcohol; the budding wings (*w*) outside these, on segments 2 and 3, are, by the same treatment, brought under view, as are also the rudiments of the sting in queen or worker larvæ (Chapter XII.), the male organs appearing in that of the drone. After sealing, the fourth segment begins to contract, and the fifth becomes partly atrophied, so that, soon, the former constitutes only a partial cover for the base of the developing thorax, and the petiole between it and the abdomen, while the latter becomes the narrow, first abdominal segment. At page 196, it has been explained that the last three segments disappear in forming the sting; and now we find the fourth forming the petiole, leaving nine of the thirteen original segments, of which three go to the thorax, and six to the abdomen.

A point in relation to the behaviour of queen grubs, as differing from that of others, chiefly referring to the facility with which the cell containing the queen nymph can be torn open, here requires careful attention, because it is so generally mis-stated. After the spinning of the cocoon, which *in no case* extends far down the sides of the cell, the worker or drone larva, as before mentioned, turns and throws up the bowel lining and contents, and casts its skin, which, by the creature's movements within the cell, becomes plastered to the walls, and joins the cocoon near the mouth end. The legs, wings, and advancing male organ or sting—depending on the gender of the grub, and which before could not be seen without treatment—are now fully visible, the name chrysalis, or nymph, being properly applied; the modelling continues, dimplings are seen, rounded forms become angular, the external skeleton gathers in density and colour, bristles appear; every organ is advancing, and, ere long, the imprisonment and the darkness are left for the heavenward flight of a new life, which gave to the ancients the name and the type of a resurrection. Huber,* especially with regard to the structure of the cocoon, fell into errors, from which he drew false deductions that are being still repeated. I give a free translation, in order to condense his meaning, which runs thus: "The worker and drone grubs form *complete* cocoons—*i.e.*, the latter are closed at both ends, enveloping all the body. The royal grubs, on the contrary, make cocoons which are *imperfect*, being open at the posterior part,

* "Nouvelles Observations sur les Abeilles," page 218, vol. i.

enveloping only the head, the thorax, and the first ring of the abdomen. This discovery has given me," continues Huber, "extreme pleasure, because it evidently shows the admirable way in which Nature has brought into agreement the different actions of bees. Queens have a great mutual aversion, blood-thirstily seeking one another's destruction. When there are several royal nymphs in a hive, the first one to hatch throws herself upon the others, and pierces them with thrusts from her sting. But she could not succeed if the nymphs were inclosed in a complete cocoon, because the silk is strong, and the cocoon of a close texture, which the sting would not penetrate; or, if it penetrated, could not be retracted, so that the queen would die the victim of her own fury. In order that a queen may succeed in killing her rivals in their cells, it is needful that their hinder part be uncovered, for it is only here that the dart will penetrate them, the head and the thorax being clothed with strong, scaly plates. The royal grubs should, therefore, furnish incomplete cocoons."

Is it true, then, Mons. Huber, that an unpoetical little grub emulates Cassius, when, in a supreme moment, he exclaims: "There is my dagger, and here my naked breast"? Iteration and reiteration, by author after author, since your admirable investigations notwithstanding, it is utterly incorrect. We should have had fewer writers, or more investigators for the microscope, since the introduction of the achromatic objective, between fifty and sixty years ago, has been fully equal to showing that no cocoon,

as already said, extends much beyond the cell mouth, the remainder of the covering of drone and worker being the cast skin; but, in the case of the queen grub, whose cocoon is really *more* extensive, and decidedly tougher, than that of the other inhabitants of the hive, the royal jelly, occupying the upper part of the cell (*a*, Fig. 48) clearly prevents the usual method of proceeding. The skin and bowel are, indeed, cast as by the worker, but they are not spread out on the



FIG. 48.—COMB AND QUEEN CELLS (Magnified Twice).

a, Queen Cell, Cut to Expose Royal Jelly and Grub at Upper End; *b*, Thickness of Cell; *c*, Dimpling Outside Cell; *d*, Spot where Bowel Contents and Exuvium are Placed

cell wall. The bowel, relatively small, and containing little waste product, is thrown against the side of the cell at *d*, Fig. 48, just below the mass of royal jelly; and here the skin of the body is placed also, where both can always be found, by opening a queen cell on the third day after sealing. During the earlier part of the changes, the developing insect adheres, by the dorsum, to the wet royal jelly, and probably

X 2

continues to take nourishment through a part of the skin. We thus see that, when the murderess arrives, nothing but the thick cell side, of impure wax, intervenes between her and her victim; the cast skin, which is extremely delicate, is absent as a lining, it is true, but the cocoon is placed as in all other cells.

Huber investigated the periods of evolution for the sexes—matters, the details of which must be treated in our Practical Section; but his results, which are constantly given in bee books, are only approximations, for, directly we attempt to systematically follow up the inquiry, we find that considerable variations present themselves: in one hive the worker bees gnawing out, on an average, on the twentieth day after the egg is laid, and in another not until the twenty-first; eggs in the same hive, and of the same hatch, especially those of drones, taking unequal times for evolution: while the seasons of the year also make a difference. Huber found that queens required sixteen days to mature, workers twenty-one, and drones twenty-four. But even within the hive, I find the queens can, by management, be delayed so as to require nearly eighteen days, the workers twenty-five, and the drones twenty-eight; while, by removal from the hive, a more considerable retardation may be occasioned. The more rapid normal development of the queen is highly interesting, and its reason is evident. As queens fight, the first hatched has the best chance of being the survivor, so that there is a constant selection in favour of those rapidly maturing. There is, in a modified degree, a similar selection of workers, for any in-

crease in the time occupied before they leave the cell would heavily handicap the stock, and so decrease its chance of sending off a swarm, thus preventing the mother from leaving descendants by her daughters; and, since bees do not generally produce drones until swarming has for themselves reached probability, she would also have less chance of leaving descendants by her sons.

In closing this chapter, which also terminates one section of our studies, we must be impressed with the mysterious division of labour between queen and worker, the latter fitted to honey and pollen-gathering, wax-secreting, comb-building, nursing, and cleaning, with every tool she can need; the former, for the duties of maternity, and for these alone, with generative organs fully equipped for the enormous work demanded of them, but that at the expense of all those parts which minister nothing to her proper functions; all originating, too, in the coalescing germ and sperm cells, endued, so far as the eye of the body or of the mind can carry us, with powers to build up, differentiate, and arrange a mechanism which, though tiny, can make us all exclaim, "We are but of yesterday, and know nothing!" And let us not here fall into a mistake far too common. No natural object receives attention that does not grow in wonderfulness under the operation, and so each one is prone to think that his particular subject of investigation has more in it than any other. We naturalists and bee-keepers, as we watch and study the little insect that has given so much delight, are in no little danger of coming to

believe that we are contemplating the very masterpiece of creation, and that we have before us a concentration of wisdom and of wonder for which we should look elsewhere in vain. It has, by example, almost become a fashion to tell us, as a modern manual does, in reference to the production of queens, that "we have here a fact which has no *parallel* in natural history." A broader view will show, as we have just seen, that not only is this untrue, but that quite as surprising and unlooked for methods of sexual differentiation not infrequently occur. Our very mistakes may help us upward; for should not the fact that the things which at first we think little we afterwards discover to be great, and that the more we study, the more we find there is to learn, rather prove to us the unwisdom of supposing we have *already* unfolded the greatest of all wonders, teaching us that, as yet, we only discern few marvels where there are many, and that, did we know Nature as she *is*, we should see neither less nor greater, but fulness of beauty everywhere, the exponent of a wisdom past finding out? The oppressive infinitudes of astronomy, and the equally inconceivable minuteness revealed by the microscope, are but two phases of the frame of the universe, which has touched infinity at every point. Already, indeed, we get glimmerings that the recognition of this fact will be a goal of science, which is now opening up to us, that not only animals and plants have their wonders, but that the very atoms are miracles of form and force, bound together by relationships which are endless.

CHAPTER XV.

BEES AND FLOWERS MUTUALLY COMPLEMENTARY.

Outline of Subject—Old Errors and Modern Discoveries—Cleistogamous Flowers—The Part played by Bees and Insects—The Banquet offered by the Flower—The Parts of the Blossom—The Ovule and Ovary—Embryo Sac—Formation of Embryonal Vesicle—Pollen: its Structure—Pollen Tubes—Impregnation—Anatropous Ovule—Union of Nuclei—Formation of Embryo and Seed—Monœcious and Diœcious Plants—Aucuba japonica—Hazel Nut—Nectaries—Extra Floral Nectaries—Differences between Nectar and Honey—Position of Nectary—Nectar Cells: Microscopic Examination of; In Pelargonium and Hyacinth—Aphide Honey.

THE fact that bees gather both pollen and nectar from blossoms has already been considered; but we have yet to learn, why the wants of bees, in all their genera and species, are supplied by the floral world. The answer to this inquiry brings before us a new meaning to the existence of all these insects, as a part of that frame of nature in which nothing is really isolated, although the bonds of mutual dependence may not always be apparent. Let us, first,

look at the matter in outline, filling in, hereafter, such details as may seem necessary. Plants blossom in order that seed may be produced and perfected, and the race continued. But before seed, in the true sense, can be produced at all, pollen, which is borne by the anthers, and which we have all noticed, as the abundant orange-coloured dust of the lily, *e.g.*, must be placed upon a certain special part of the flower, called the stigma, a fact discovered by Sir T. Millington two centuries ago. Should the pollen be of a suitable kind, and the stigma in a receptive condition, a delicate thread, called a *pollen tube*, is thrown out, by the pollen granule, into the seed vessel, by which the seed becomes fertilised, and, when mature, capable of germination. The great majority of flowers possess both anthers and stigmas. They carry the two sexes within themselves; and we might suppose that, this being so, the form of the flower would secure the transmission of its pollen to its stigma, in order that the end of its being might certainly be accomplished.

So thought the older botanists, and were, in consequence, puzzled in explaining the reasons for the forms of the blossoms they examined. It was pointed out, however, as long since as the close of the last century, by a keen observer of Nature—Sprengel—that the structure of a large number of blossoms was such as seemed designedly to render this simple arrangement impossible. His observations for many years bore no fruit, and appeared to be overlooked; but, during the last two decades, systematically-conducted experiments and extended observations by many

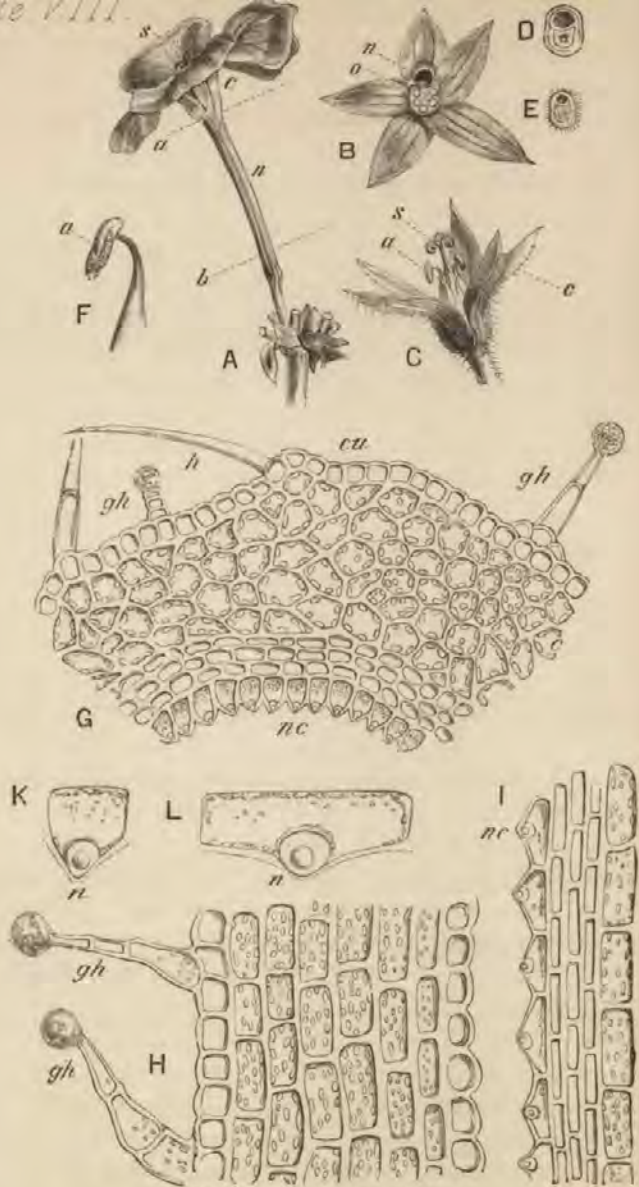
naturalists, especially Hildebrand, Hermann Müller,* Delpino, and, above all, Charles Darwin,† have put the whole question in a new light, and reduced isolated facts to a law, which extends beyond the range of botany. It is now shown that conspicuous flowers, generally speaking, are especially modelled to *prevent*, or at least impede, fertilisation, by the pollen they themselves produce; while marvellous contrivances are exhibited to secure pollen from some other plant or flower of the same species; for, amongst those that have been studied in reference to this matter, there exists but a very inconsiderable number of real or apparent exceptions; whilst the latter, under renewed examination, are not infrequently affording delight, as they are found to possess some unsuspected adaptation to *cross-fertilisation*, which, in occasional instances, especially amongst the orchids,‡ is so droll as to sound rather like the outcome of a rampant fancy than a narration of sober fact. I am not unmindful of the existence of blossoms, denominated *cleistogamous*, produced, under certain conditions, by some plants, and which *must*, by their structure, be self-fertilised; these we shall find, when they presently come before us, are produced rather as supplementary or alternative than exclusive organs of reproduction. The protest made by Nature, for some profound, perhaps inscrutable reason, against continuous in-breeding, applies, then, no less to plants than to animals, to flowers than to bees.

* "Die Befruchtung der Blumen durch Insecten," 1873.

† "The Effects of Cross and Self-Fertilisation," and "The Different Forms of Flowers on Plants of the Same Species," 1877.

‡ "The Various Contrivances by which Orchids are Fertilised by Insects." C. Darwin. 1877.

But blossoms are fixed, if not even isolated. How is the all-needful, fertilising dust to be carried from one to the other? For some, the work is done by the wind, as when the blossoming corn is made to gently rustle, or the lightly-suspended catkin of the willow is vibrated in the upper boughs. Pollen, in all such cases, having been formed, in countless millions of granules, is, at its proper season, wafted by every breath of air to the stigmas, made branched and hairy to increase the chance of grasping it as it travels past. But by far the greater number of flowering plants confide to insects the duty of bringing about those unions which, without them, would never be effected. And, amongst insects, the whole family of the *Apidæ* are of the highest utility, followed by butterflies and moths, while flies, and even humble thrips, play their part; but it is the hive bee especially that has been made the complement of the blossom, the love messenger of the little beauties of our woods and fields, supplying the eyes and wings which have been denied to the flower itself. As, then, the visits of insects are essential to the existence of most plants, the flower secures these by spreading a banquet, which it decorates with its own beauty, and perfumes with its own sweet breath. Pollen, it is true, is necessary for blossoms themselves, but the amount produced is, without exception, enormously greater than that required for mere fertilisation; and the excess is the flesh-forming food of the pollen-gatherer; while nectar—the basis of honey, the heat and force-former, as grateful to the insect palate as our own—is yielded, in the



NECTARY AND NECTAR GLANDS.

A, *Pelargonium* Blossom—*s*, Stigma; *c*, Calyx; *n*, Nectary. B, Calyx, with Ovary in Cross Section—*n*, Nectary; *o*, Ovary. C, Blossom, side view (Corolla removed)—*s*, Stigma; *a*, Anther; *c*, Calyx. D and E, Cross Sections of Ovary through lines *a* and *b* of A. F, Stamen—*a*, Anther. G, part of E (Magnified 180 times)—*cu*, Cuticle; *gh*, Glandular Hair; *h*, Hair; *nc*, Nectar Cells. H, Longitudinal Section through Upper Part of Nectary—*gh*, Glandular Hairs. I, Longitudinal Section through Lower Part of Nectary—*nc*, Nectar Cells. K and L, Sections of Nectar Cells (Magnified 500 times)—*n*, Nectariferous Nucleus.

great majority of instances, solely for her benefit. Thus, then, insects perpetuate flowering plants, and flowers continue the existence of insects, both being but mutually sustaining parts of one great whole.

Let us now endeavour to follow the details by which the general principles that have been sketched are applied. If we take an ordinary flower—and, for our present purpose, no better example can well be suggested than the universal favourite, the common geranium (pelargonium) of our gardens (Plate VIII.)—and look at it from the outside, the first part brought under our notice is a kind of cup—the calyx (*c*, A and C)—here green, although in many flowers—the fuchsia and larkspur, *e.g.*—it is coloured. Before the blossom opens, when it is in the bud condition, this cup incloses the internal parts, which are then in the process of development, and protects them, in their soft and tender condition, from external injury. The calyx bursting as its contents develop, the most conspicuous part of the flower, the *corolla*, made up, in the pelargonium, of five, generally scarlet, petals, begins to expand. The main function of the corolla, in the greater number of blossoms, is to attract insects, both by means of colour and scent. Within the corolla we find the anthers (*a*), seven in number, and differing altogether in shape and appearance, both from the sepals—five of which make up the calyx—and from the petals forming the corolla. The calyx and corolla are of subordinate importance, and may be regarded as protective and decorative in character; but the anthers, which, together with the stalks (the filaments) carrying them,

are called stamens, are absolutely necessary to secure the reproduction of the plant. The anther is a double bag, or, as in this instance, a pair of such, containing a quantity of tiny granules (pollen), which, in reality, are individually highly organised parts, capable, as already hinted, of bringing about the wondrous process of fertilisation. Lastly, within the space lying between the encircling stamens, and occupying always the centre of the flower, lie the female reproductive organs (*s*, *C*), collectively denominated the pistil. This assumes very diverse characters in different blossoms; but here, as in all the more perfect forms, it consists of three parts, the bottom one being a pouched cavity (*o*, *B*), or hollow receptacle, called the ovary, because it contains one or many minute egg-like bodies (the ovules), each inclosing a germ cell awaiting impregnation. Rising from the apex of the ovary is a stalk-like part (the style), seen beneath *s*, *C*, and surmounted at its summit by a body of peculiar structure, called the stigma, which, at a certain point in its development, becomes capable of receiving the pollen granules—really the homologues of the sperm cells of the drone (page 216). The flower, as such, in all cases is a means, not an end, and, as the latter is accomplished, it disappears. The corolla, having caught the insect's eye, dries; the stamens, having yielded their sperm, wither. The stigma and the style, having performed their office, dry and shrivel, and nothing is left except the ovary, which is, in some cases, surrounded by a persistent calyx. The ovary now grows and develops into what is called the seed vessel, but

botanically, the *fruit*; here, at length, we have the seeds, which are the ripened ovules, while the seed vessel is the ripened ovary. But the change from ovule into seed is not merely one of growth; it depends upon the formation within the ovule of the

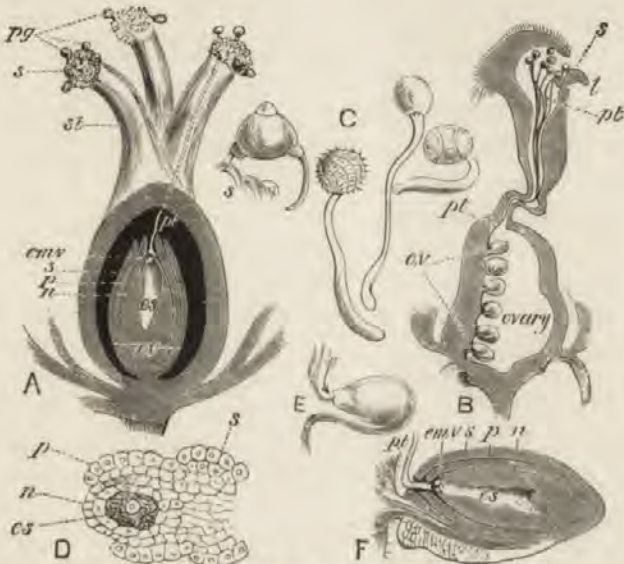


FIG. 49.—OVARIES, OVULES, POLLEN GRAINS, AND TUBES.

- A, Section through Ovary of Buckwheat (*Polygonum fagopyrum*)—*s*, Stigmatic Surface; *pg*, Pollen Grains; *st*, Style; *pt*, Pollen Tube; *ov*, Ovule; *n*, Nucellus; *p*, Primine; *n*, Nucellus; *es*, Embryo Sac; *emv*, Embryonic Vesicle. B, Section of Pistil of Pansy (*Viola tricolor*)—*s*, Stigma; *l*, Lip; *pt*, Pollen Tube; *ov*, Ovules. C, Pollen Grains Various, Emitting Tubes—*s*, Portion of Papillose Stigma. D, Ovule at a very Early Stage—*n*, Nucellus; *es*, Embryo Sac forming; *p*, ditto Primine; *s*, ditto Secundine. E, Developed Anatropous Ovule of *Viola tricolor*; Arrow indicating the Micropyle. F, Section through same, more enlarged—*es*, Embryo Sac; *emv*, Embryonic Vesicle; *pt*, Pollen Tube; *s*, Secundine; *p*, Primine; *n*, Nucellus.

embryo, which is itself the outcome of the definite process of fertilisation, now to be examined in detail.

Taking a blossom of buckwheat, well-known as an

abundant honey-plant, removing the corolla, and making a section through one of the ovaries, we find, within a cavity, the ovule (*ov*, A, Fig. 49), which, on account of its being straight instead of curved, and solitary instead of one of a number, is an excellent subject for study, and, for the present, may serve as a type of those formed by flowering plants in general. When examined minutely, it is observed to consist almost entirely of cellular tissue—*i.e.*, of a number of minute sacs, similar to those at G (Plate VIII.), placed side by side, in close juxtaposition, forming (*n*, A, Fig. 49) the nucellus of the ovule, which is enveloped in two coatings of firmer texture, called primine (*p*) and secundine (*s*), which grow up over its surface in its early days, as shown at D. These surrounding layers, however, are never continuous over the apex of the ovule, where they leave an open channel, called the micropyle, quite similar in function to the micropyle of the egg (page 231), and here permitting communication with the nucellus, and a large cavity within it, called the embryo sac (*es*). In the vast majority of plants, the two sides of the ovule are unequally developed, so that, during its growth, it is made to turn partly or completely over, as in the anatropous ovule (E), where the arrow indicates the micropylar aperture, or in the ovules of *Viola tricolor* (*ov*, B), one of which is shown more enlarged at F.

The extremely interesting and instructive history of the formation and development of the embryo sac, with the mystic and involved movements which prepare for and accompany fertilisation, can only

here be touched upon. A cell near the apex of the nucellus undergoes division, which is repeated until a line of cells, with thick walls, has been formed. The lowest cell of the number now enlarges greatly, at the expense of the others, which are absorbed, and an enormous cell (the embryo sac, *es*, A and F) results. During the growth of the latter, its nucleus divides, and the two new nuclei travel to its opposite ends, a large central

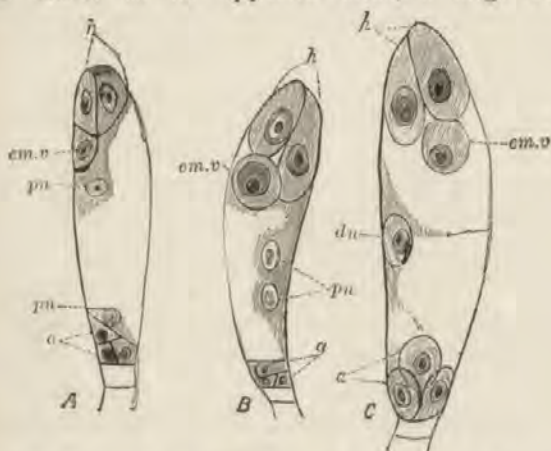


FIG. 50.—EMBRYO SAC, BEFORE FERTILISATION, IN THREE STAGES OF DEVELOPMENT.

A, B, and C—*h*, Helper Cells; *a*, Antipodal Cells, derived from Division of Original Cell Nucleus; *pn*, Polar Nuclei; *dn*, Definitive Nucleus; *em.v*, Embryonal Vesicle.

sap cavity, called a vacuole,* being formed. These nuclei, now stationed at the upper and lower extremities of the embryo sac, twice divide into two,

* The life of the cell inhere in its protoplasm. When this separates and gives place to cell sap, the spot occupied by the cell sap is called a vacuole.

four nuclei resulting in each case. Mysteriously, one nucleus starts from each end (pn , pn , A, Fig. 50), approaches (pn , B), and at last meets, its companion in the centre, and coalesces with it to form the definitive nucleus (dn , C). These two nuclei are called the polar nuclei. Round the two sets of the three remaining nuclei a process of free cell formation begins, resulting in three cells at each end of the sac instead of three nuclei. Those at the lower end (a , B and C) soon become surrounded with cell walls, while those at the micropylar (upper) extremity remain naked, and constitute the egg apparatus. Two of these lie above the third, the latter constituting the oosphere, or embryonal vesicle (*em.v*), which has its nucleus lying at its lower end. Generally, all three cells of the egg apparatus position themselves in contact with the wall of the embryo sac, which is, at this time, awaiting fertilisation from the pollen previously placed on the stigma, it may be by wind action, by the gardener, or by the little professional pollen-carrier, the nature of whose burden we must now endeavour to understand.

Pollen granules vary greatly in form, colour, and size. They are frequently approximately spherical, sometimes oval, triangular in the fuchsia or evening primrose, hexagonal in the chicory, covered with minute spines in the hollyhock and aster, curiously banded in the Passion flower, spirally grooved in the musk; while they are, in these and other similar plants, delicately coated with an oily body, giving them adhesiveness, and aiding the bee in packing them upon the legs. When cut into sections, they reveal a complex

structure: hollow within, they are filled with a very granulous protoplasm, with many oil globules; their solid coat is formed in two layers, an inner and an outer, called *intine* and *extine*. The pollen grains are developed within the anther, by constant segmentation of the contents of the latter. It appears that, when the grains become isolated from each other, the nucleus of each one divides into two unequal parts, the smaller of which attaches itself to the wall of the granule. When the pollen grain is placed upon the moist stigma, so that nourishment is given to it, the interior parts grow, and burst the exterior enveloping coat (the *extine*), at points where it is curiously thinned down, while the *intine* is correspondingly thickened—the blunt angles of the pollen of *epilobium*, e.g. (D, Fig. 57), have a delicate pellicle of *extine* only, but here the *intine* (*ti*) is extremely strong and dense; the latter, therefore, remains unruptured, and holds the protruding interior, elastically extending with it (E), so that, under favourable conditions, a tube of extraordinary length is developed, through which the larger nucleus at last passes. Pollen grains, placed in soda-water sweetened with a little sugar or honey, will, if kept in a genial temperature, grow under the microscope, giving some such forms as shown at C, Fig. 49. They may often be found in the stomach of the bee with a tube partly developed, while in the later food of the larvæ this phenomenon is quite common.

During the curious sequences represented by A, B, C, Fig. 50, the stigmas, usually covered by little papillose bodies, coat their surfaces by secretion

Y

of a sugary, glutinous fluid, which causes the pollen grains to adhere; the pollen tubes, which seem to receive nutrition as they push forward, now penetrate, with astonishing rapidity, and to surprising distances,* either passing through the channel of the style (*pt*, B, Fig. 49), or its loose conducting tissue (*st*, A), into the cavity of the ovary, where, in the darkness, they travel on, as though endued with intelligence, unerringly finding the apertures in the primine and secundine (the micropyle), by which one enters and applies its now swelling end to the extremity of the embryo sac. The two upper cells of the egg apparatus (*h*, C, Fig. 50) in some cases absorb the end of the wall of the embryo sac; but always—by methods, subject to variations in different orders—the pollen tube transfers its protoplasm and nucleus, by the agency of these helper cells, to the embryonal vesicle. Since every ovule needs a pollen tube to fertilise it, the number of tubes requisite will depend upon the number of ovules, but usually many more are produced than can be utilised. In the buckwheat, *e.g.* (A, Fig. 49), we find but one ovule in each ovary, while in many plants, especially orchids, they are multitudinous. At B (the ovary of the pansy), six are represented, but many more actually exist; and here we notice how beautifully suited to the exigencies of fertilisation is the turning of the ovule by unequal lateral development. Had these six ovules stood straightly up, like that of the buckwheat, their micropylar apertures would have been placed in an exceedingly unfavourable position for

* In the common crocus, the style is frequently several inches in length.

meeting the entering tubes; but the tiny cavity is turned round from the centre, to face the wall of the ovary (F), which is slightly hairy within. Clinging to this hairy surface, the tubes feel their way along, to find, and at once enter, the point they seek. The helper cells (*h*, Fig. 50) now disappear, while the embryonal vesicle becomes granular, and *two* nuclei can be detected in it. One of these is the nucleus of the oosphere, or embryonal vesicle; the substance of the other has, doubtless (according to Sachs), been derived, through the helper cells, from the pollen tube. These two nuclei, male and female in their origin, meet and coalesce, constituting the nucleus of the fertilised embryo, or new individual, which now surrounds itself with a cellulose wall, and so starts an existence, which yet depends upon nurture derived from the female parts of the parent flower. When it has acquired some development, and a supply of food sufficient to enable it to initiate a separate existence, it will be cast off as a mature seed.

We have, up to this point, spoken of flowers as though they invariably carried both stamen and pistil, and usually this is the case; but exceptions are not infrequent. Every one knows that, in the melon, vegetable marrow, cucumber, and other plants belonging to the order *Cucurbitaceæ*, some of the flowers are male, while others are female, the latter bearing the fruits. In these cases, it is obvious that the pollen necessary for the fertilisation of the ovule must be carried, by some means, from one form of flower to the other; and when, by the method of culture, insects

are excluded, the operation denominated "fertilising," or "setting," is undertaken by the gardener. The two genders of unisexual flowers, sometimes placed, as in the vegetable marrow, on different parts of the same plant, hence called *monœcious*, are frequently produced on distinct plants—then called *diœcious*, meaning *two houses*—which are, necessarily, the complements to one another. This fact was known to Herodotus, in the fifth century before Christianity, who describes the process of "caprifigation"—the transference of pollen from the male blossoms of one tree to the female blossoms of another—by which a crop of dates was insured on the Egyptian palms.

In our own day, a curious instance has occurred, in the case of the *Aucuba japonica* (the common blotched laurel), a single plant of which was long since introduced into this country by the Dutch. This solitary specimen, from which, up to a few years since, all the countless plants decorating our gardens and shrubberies had been derived, by cuttings, happened to be a female. The myriads of ovules formed in all the inconspicuous, chocolate-coloured flowers of the descendants of this parent, of course invariably withered for want of fertilisation; but, a few years since, the male *Aucuba* reached us, and beautiful scarlet berries began to be formed, and our ancient friend made additionally attractive as a decorative plant. These berries gave us new individuals, exhibiting variations from the parents, and yielding some male, some female, flowers, so that the berrying of the laurel is already general.

The common hazel bears unisexual flowers, which are

utterly dissimilar ; the males (*a*, Fig. 51) are grouped in drooping lines, called catkins, each containing something more than a hundred flowers, which come out soon after Christmas, remain on the tree for a few weeks, and then drop. But they have accomplished their work, for the ten or twelve anthers each blossom carries furnish abundant pollen, which, shaken by every breeze, and being non-adhesive, gently falls through the spreading branches below, where we may find



FIG. 51.—INFLORESCENCE OF NUT.

a, Staminate (Male) Catkin of Nut ; *b*, Pistillate (Female) Blossom of ditto ; *c*, Pistillate Blossom, Unopened.

small, hardly observable female flowers (*b*), consisting of hairy, branched stigmas, crimson in colour, and rising from amidst a few small scales, which conceal the ovary. The stigmas catch the dropping granules, the pollen tube is thrown out, and fertilisation follows, preceding, in order of time, the expanding of the leaves, which would, if opened, seriously impede the operation. The necessary abundance of pollen, since so much is inevitably

wasted, gives an excess, of which the bees take advantage; and often, in the early spring, the stocks are greatly helped by the catkins, not only of the hazel and other nuts, but also of the beech, the poplar, and the willow (of which the two catkins are represented in Fig. 52). It is curious that, in the case of the weeping willow, notwithstanding its wide distribution, only pistillate (female) trees are in



FIG. 52.—CATKINS OF WHITE WILLOW (*SALIX ALBA*).

A, Staminate (Male) Catkin; B, Pistillate (Female) Catkin.

cultivation, which must have all originated from a single parent. The blossoms just mentioned are wind-fertilised (except the willow, whose position is intermediate), and form a few examples of those called anemophilous; while those depending on insects are denominated entomophilous.

Before proceeding to examine the various remarkable modifications made in flowers, in order that the pollen produced by their anthers, in the closest proxi-

mity to the stigma, should yet not fertilise the latter, we must discuss the manner in which the nectar is produced, and placed so as not only to attract the insect, but also force it, while taking its repast, to deposit pollen, brought upon its body, on to the stigma.

It is more convenient than accurate to speak of "honey-yielding plants," and of bees gathering honey; for the fluid secreted by the flower is unlike honey in more particulars than one, and is denominated nectar, while the part by which it is yielded is called a nectary. Although it is certain that the character of the secretion varies considerably in different plants, analysis has shown that, in a large proportion of instances, the sugar it contains is identical with that derived from the cane or beet-root, while the sugar of honey is similar to that of the grape. From what has already been said of the glandular and tongue structures of bees (pages 81 and 101), it is clear that a salivary secretion is added to the gathered nectar, and that this, like the saliva in our own case, converts the cane into grape sugar; and probably also, as with ourselves, this is an initial step in assimilation, since cane sugar is actually poisonous to the blood, while grape sugar acts within it as a normal producer of heat and force. Many flowers are especially contrived for fertilisation by moths and butterflies, and there is strong reason for supposing that these latter insects produce exactly the same alteration—technically, "inversion" of the sugar of nectar—as our bees.

From what we know of the chemical changes occur-

ring during the germination of seeds, and in leaves when stimulated by light, we should expect sugar to be present in considerable quantities in flowers, where growth is so rapid, and cell energy so apparent. Many careful observations, made of late years, by botanists, in various countries, have shown, amongst other interesting facts connected with the existence of nectar in plants, that flowers contain it in quantity, in their tissues, even when no nectary is present to secrete it; and also that, in vegetative organs, quite apart from the inflorescence, nectaries are occasionally present—*e.g.*, in the bracken fern (*Pteris aquilina*), nectar flows from small, pale swellings at the bases of the secondary petioles; and the stipules (or leaflets on the leaf-stalk) of beans are nectariferous, as are also small glandular prominences on the leaf-stalk of a species of *Prunus*, and little, brownish pittings in the leaf-blade of some laurels. From the latter I have sometimes seen hive bees gathering industriously, while their visits to bean stipules are quite *en règle*. It is here very interesting, while practically important, to note, that experiment has shown that emission of water vapour into the atmosphere, and emission of nectar on the surface of the nectary, are so related, that what favours the one retards the other, the damaging effect of a prevailing east wind being thus perfectly explained. In the flowers, nectar is usually furnished most abundantly in the early morning, diminished till afternoon, and again increased towards evening. Although high temperature favours secretion, flowers of the same kind yield larger amounts in colder than in warmer climates.

To trace out the probable development of the nectary is beyond our limits; but, in a word, if it be granted—and experiment is conclusive on the point—that intercrossing does lead to greater vigour in the resulting seed, then any variation making intercrossing more certain will lead to a selection favourable to the individual presenting that variation; so that transudation of sugary matters forming a rudimentary nectary, and so attracting insects, will tend to establish and extend the variation, by which the flowers will become permanently nectariferous.

The position of the nectaries in flowers, and the organs of which they are modifications, differ with the kinds of insects for which they are suited; some lie almost on the surface of the flower—*e.g.*, in the carrot, elder, ivy, &c.—but most are situated in its deeper recesses, not only because this position draws the visiting insect well into contact with the male and female parts, but also because exposure to water, in the form of rain or dew, injures the nectar, and decreases its attractiveness. This fact is the counterpart of the enormous length of proboscis possessed by moths, butterflies, and bees. In many flowers, strange devices save the sugary fluid, even in the most persistent downpour—*e.g.*, in the upstanding white dead nettle, the upper lip is formed into an umbrella (see Fig. 66); in the *Tropæolum majus* (garden nasturtium), upright water-resisting hairs (see Fig. 55) prevent rain travelling towards the spur; and in the useful *Borago officinalis* (borage), the drooping habit of the flower, and the tube-like cavity formed between the stamens, give perfect protection.

The fact that sugar is present in flowers because of their rapid development, would lead us to expect it in greatest excess where the energy of life is most intense—and this is in the ovary; and, suggestively, it is in this neighbourhood that the nectary is far most commonly found, numerous instances presently coming before us. Curious variations, however, occur. Poplars, which are anemophilous and diœcious, yield so much sugary secretion on the stigma, whose office it is to glue down the pollen granules floating by, that the stigma really becomes a nectary; and these trees, although altogether independent of insect action,

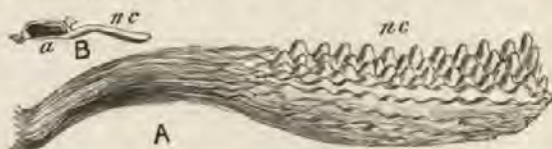


FIG. 53.—A, APPENDAGE OF ANTHER, FORMING NECTARY OF *VIOLA TRICOLOR* (PANSY), Order *Violaceae* (Magnified Twenty-four times)—*nc*, Nectar Cells, exaggerated. B, ANTHER AS REMOVED FROM FLOWER—*a*, Anther Cell; *nc*, Nectar Cells.

yet yield a restricted quantity of honey: in some, the base of the style, in others, aborted stamens, become nectar-yielding; the transuding syrupy surfaces often appear on the petals, as in some species of buttercups, where they are covered with a small, flat scale, behind which the nectar is formed; or on the sepals, as in the lime, so well loved by bees; in many, the petals are rolled into a tube, as in the columbine, hellebore, aconite, &c., and the inner end of the organ is the nectary; but in some—*e.g.*, the violet—the spur merely serves to *receive* the nectar. In *Viola tricolor* (the pansy), the larger and lower

petal is thus extended backwards, and curious appendages (*nc*, B, Fig. 53) on two anthers pass into the cavity provided, and there secrete a sweetish fluid. Perhaps no flower presents equal advantages with this to the microscopic tyro who would study the structure of the nectary, and the cells (nectar cells) which yield the secretion; for not only are these large (*nc*, A), characteristically sugar-loaf-shaped, and prominent, but they lie on the *outside* of the process (their protection being derived from the covering afforded by the spur-like petal previously mentioned), and, consequently, the difficulties of section cutting are, in this case, altogether avoided. The nectar-producing tissue is usually made up of small, thin-walled cells, containing abundant protoplasm, a nucleus, and cell sap, rich in sugar. Often the nectary shows a number of pores, or stomata, on the surface-layer of the cells which line it, and through these the nectar is poured on to the face of the organ, whence it may be sucked up by the visitors to the flowers. Where pores are absent, the covering membrane is extremely delicate, permitting either free transudation, or yielding at once, as in some orchids, to the abrading action of the insect tongue.

Returning to our pelargonium (Plate VIII.), selected because it is at command in most places, and at every season of the year, we find, running down the flower stalk, and immediately under the uppermost and broadest sepal, an enlargement of the stalk itself, marked off by inconspicuous grooves, and terminating in a small bulbous expansion a little below the line *b* (A), and which is often purplish in colour. This is

the nectary, and is really formed by carrying the upper part of the calyx down the stalk. If we compare its position and relations to the rest of the flower with those of the *Tropæolum majus* (Fig. 66), which is of the same order (*Geraniaceæ*), we shall find that the difference lies in the latter nectary being free, while the former is attached (adnate) to the pedicel, or stalk, of the flower. If we now remove the petals, and look at the calyx from the front, we see into its opening (*n*, B). Making cross sections through the lines *a* and *b*, we find the nectary wider above, as at D, and narrow below, as at E. A keen razor, dipped into methylated spirit, will take off slices sufficiently thin for microscopic examination, under a cover glass, in water. Cutting D longitudinally, so that the nectary is divided, and then removing a thin slice from that which forms the upper part of the Figure, and magnifying about 200 diameters, we find the outside to consist of cuticular cells, carrying glandular hairs (*gh*, H), which secrete a resinous body, of strong odour. The cells on the opposite side of the section are not unlike those of the external cuticle, because they have here no secretory function, although they constitute the lining of the upper part of the nectary. Taking a section (G) from the face of E, which lies in the line *b* (A), we discover the hairs and cuticle to be of precisely the same character as those previously noticed; but the lining cells (*nc*) of this part of the nectary are totally different, extending inwards by almost pointed prominences. Now cutting E longitudinally, and taking from it a thin section, we find the lining cells

all pointed, as at I, where they face those which lie near the mouth of the nectary, as a part of H. The structure of the pointed cells is quite special, their contents, as seen under high magnifying powers, being distinctly granular, peculiarly so near the cell-wall, which, at the prominence, is excessively thin, and has, lying immediately within it, a globular mass of highly refractive protoplasm (*n*, K and L), containing a distinct nucleus. This is the active agent in accomplishing the secretive act, and the surface of the cells here, in healthy plants, and in proper conditions of the atmosphere, will always be found to be coated with a layer of nectar.

We may study, similarly, the three nectaries of the common hyacinth. If the corolla be removed, we find the flask-shaped ovary giving indications of being formed by the fusion of three parts. The furrows running between these carry, near their upper ends, tiny beads of nectar, secreted from a tube-like cavity, running down between the cells of the ovary; and, by making cross sections, we get an opportunity of examining the nectar cells. But, in some cases, we find no superficial layer possessing the secretory function, but an alteration in the underlying cellular tissue, which carries its nectar onwards to a pore passing through the ordinary epidermal cells. This structure obtains in the raspberry (Fig. 70), where a continuous line of pores (*no*), commonly covered by beadlets of nectar, easily seen by a lens, surrounds the drupels; the nectar being, of course, secreted by nectar cells (*nc*), which are not superficial, but form a part of the receptacle of the blossom.

It would be well for apiculture if plants yielded to bees no other nectar than that flowing from their blossoms; but, unhappily, a sort of second-hand honey, primarily derived from plant juices, and of very objectionable quality, is frequently gathered from the insect pest, the *Aphis*, or plant louse, in such quantity as to utterly ruin the legitimate harvest. The whole question of this pseudo-honey has very great interest, and demands the careful attention both of the gardener and bee-keeper.

None can have failed to have noticed the shining and gummed appearance frequently presented by the leaves of the lime, the sycamore, the oak, the maple, and the elder, particularly in hot weather; while the plum, the apple, rose, and currant—amongst many other plants and trees—are often brought into an almost disgusting condition from the glutinous liquid which covers them, and which, because anciently supposed to be a deposition from the atmosphere, received and retains the name of "honey dew." Kirby and Spence, in their "Introduction to Entomology," say: "You have, doubtless, observed what is called the honey dew, upon the maple and other trees, concerning which the learned Roman naturalist, Pliny, gravely hesitates whether he shall call it, the sweat of the heavens, the saliva of the stars, or a liquid produced by the purgation of the air. Perhaps you may be aware that it is a secretion of Aphides, whose excrement has the privilege of emulating sugar and honey in sweetness and purity." *De gustibus disputandum est*, and certainly here but few would endorse the closing words of these authors. Plants

rarely, and probably only in diseased conditions, secrete excessive quantities of sweet liquid, which, oozing from various parts of their surfaces, gives the eager gatherer material that is above suspicion; but ordinary honey dew is now universally conceded to be

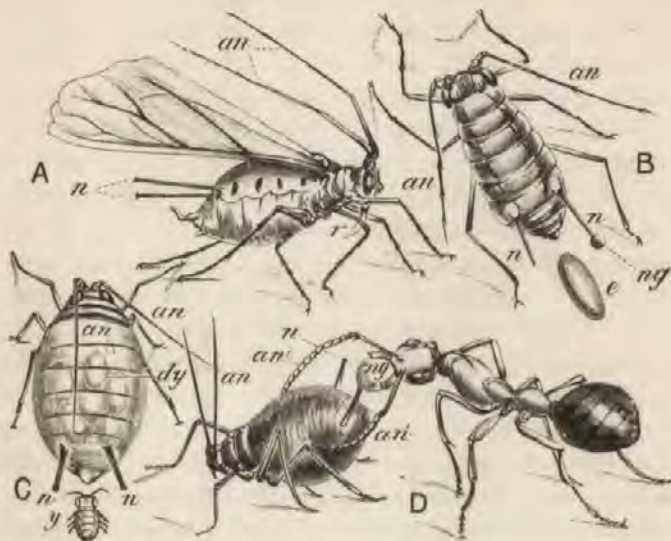


FIG. 54.—APHIDES AS NECTAR-PRODUCERS.

- A, Rose Aphid (*Siphonophora Rosae*), Winged Viviparous Female (Magnified Ten times)—*an*, Antennæ; *n*, Nectaries; *r*, Rostrum, or Proboscis. B, Wingless Oviparous Female of same—*an*, Antennæ; *n*, Nectaries; *ng*, Nectar Globule; *e*, Egg just laid. C, *Aphis Scabiosae* (Aphis of *Scabiosa arvensis*), Wingless Viviparous Female (Magnified Sixteen times)—*an*, Antennæ; *n*, Nectaries; *dy*, Developing Young; *y*, Young Aphis, just born. D, *Aphis Sambuci* (Aphis of Elder Tree), Wingless Viviparous Female, with Ant Feeding on (*ng*) Nectar Globule—*an*, Antennæ; *n*, Nectaries; *ant*, Antennæ of Ant.

the product of the Aphis. When the gummed leaves are lifted, they will be found to be infested beneath by colonies of these creatures, some winged and some wingless; and a careful examination will generally

show that they are provided with two short tubes, called the nectaries (*n*, *A*, Fig. 54), by which they are enabled to eject a sweet fluid.

Leaves are constantly forming starch, which is at once converted into the soluble form, sugar; so that the *Aphis* is, perhaps, provided with saccharine substances in such quantity that the excess must be drained off. Standing, two or three years since, in the shadow of a lime tree, I saw falling, in the sunlight, a thick, constant shower of minute drops, which were being expelled from the anal apertures and nectaries of the *Aphides* infesting the leaves. The necessity for this vigorous ejection is apparent; without it, the closely-packed colonies would soon be hopelessly fixed to the leaf, and to one another. The grass beneath the tree was thickly gummed, while the upper surface of every leaf was closely covered, and not a few bore incipient drops at their points. Other instances quite as remarkable have attracted my attention; in one case, that of a sycamore, overhanging some paving-stones, the latter were rendered actually dangerous to the pedestrian; and one of my apple trees ("Sturmer Pippin"), this summer, became, in very few days, so covered, that every leaf carried hundreds of the *Aphis Mali*, and every fruit was running with what might have passed as a compound of treacle and soot. Few botanical families appear to be altogether proof against the attack of these pests, which are all but universally distributed, and of which Beckton,* in his magnificent work, describes about 300 distinct species, the oak suffering from about six, the birch.

* "Monograph of the British Aphides," Ray Society, 1883.

willow, and fir, from eight each, the elm from four, and the currant bush from three.

Their rapid multiplication and very injurious effect cease to be a wonder when we learn something of their habits and capabilities. The male only appears amongst them at intervals, which may be distant, and he has only been well made out by dissection in about twelve species. An impregnated egg having been deposited, very many generations of individuals, formed by a process of interior budding, and born alive, will succeed one another, before the cycle is completed, and the fully-sexed female and male give again origin to the impregnated egg. Usually, some days after the appearance of the male, the oviparous female (B, Fig. 54) begins to deposit her eggs, which, in most species, are relatively enormous, each one (*e*) equalling in length half the body of the mother. When deposited, they are coated over with a glairy fluid, attaching them to twigs or stipules; they are then pale, but soon become brown or black, and are capable of bearing the most intense cold of winter. Nor are the Aphides themselves much less hardy. Beckton states that he witnessed the hatching of a young Aphis from the eggs of *Siphonophora Rosæ* (the Rose Aphis), on March 12, 1873, when the thermometer stood at 25°, and most species can endure lower temperatures without visible injury. The insect, after leaving the egg, very rapidly grows, and quickly attains its full size, exhibiting in its pseudovaries (false ovaries) developing larvæ, which soon begin to make their escape at the rate of many daily. Indeed, the body cavity of the viviparous Aphis, during the summer

time, is almost exclusively occupied by the embryos (*dy*, C, Fig. 54) and the digestive apparatus. If an adult female be removed from the under side of the leaf of a rose bush, and the abdomen snipped, as many as thirty immature Aphides may often be seen to escape, by applying a little pressure, under the microscope. The embryos are in all stages of development, those lying nearest the body aperture being the largest, and showing the eyes, antennæ, and limbs fully formed. The description previously given of the ovaries of the queen bee (page 213) will aid in understanding the ovarian chamber in this smaller insect. They are gathered into tubes, which are, again, formed into two bundles, disposed laterally, each communicating with its own oviduct. The upper extremities of the ovarian tubes are very attenuated, and lead into a chamber where the germinal matter is elaborated. Here nucleated cells are visible, which, according to Brandt,* have an amœboid, movable nucleus, and correspond to the ordinary germinal vesicles, with their usual spot; the ovum becomes the larva, which is extruded fully formed, as we have already seen. The progeny, even at the time they quit the parent, show the traces of another generation within themselves; thus, a single insect, hatched from one of the shining black ova, may, during her lifetime, be the mother of many billions of young. Réaumur calculated that one *Aphis* may give origin to the enormous number of 5,904,900,000 individuals during the month or six weeks of her existence. Happily, Aphides have many insect enemies, which, as our friends and helpers, must

* " Ueber das Ei und seine Bildungsstätte," 1878.

receive attention before we close, while rough weather plays havoc with them, rainstorms sweeping them away by myriads; but, upon the supposition that no casualties occur, Réaumur's figures are far too low, and Tougard and Morren show that a quintillion are within the efforts of a single mother; and Professor Huxley* gives the amusing calculation that, assuming an *Aphis* to weigh $\frac{1}{10000}$ gr., and a man 285 lb.—*i.e.*, 2,000,000 grains—then, the tenth brood of one parent, without adding the products of all the generations which precede the tenth, would contain more ponderable substance than 500,000,000 of such men—*i.e.*, more than the whole population of China.

Entomologists formerly thought that the production of the male which consorted with the female was brought about in anticipation of the close of the season, so that the wintering egg might be produced; but this does not appear to be accurate, and recent observations show that viviparous reproduction may be continued during several seasons, but that, at length, recourse to a new infusion of vitality by ordinary sexual means becomes necessary. A scarcity of food tends to the formation of winged females (A), capable of repairing to new pastures. These are invariably viviparous, while the wingless females may be either oviparous (B) or viviparous (C), from which it is noticeable that the larva is expelled tail foremost.

Ants are particularly fond of the sweetish exudation of the nectary, and they frequent the haunts of the *Aphis*, beating on the sides of the insects with their antennæ, when the liquid is at once driven out, as

* Huxley "On Organic Reproduction of *Aphis*."

seen at *ng*, B and D, the ant in the latter figure greedily swallowing what the Aphis offers. Linnæus, in consequence, called the latter insect the cow of the ant ("*Aphis formicarum vacca*"), and Darwin and Sir John Lubbock, amongst others, have shown that the ants almost literally milk the Aphides, which seem to attempt to retain the secretion until the ants are ready to receive it, of which they give indication as just now noted. The demand, unfortunately, is in no way equal to the supply, and so this aphide honey is thrown out, to fall on to the upper surface of the leaves, where it is gathered by bees, especially after rain, which renders it sufficiently liquid to permit of its ready removal; but its taste is mawkish, its odour not pleasant, and its colour often as dark as treacle, and of a dirty hue. That gathered from the sycamore and oak is extremely black, and ought not, in my opinion, to be regarded as fit for human consumption.

All are interested in reducing the numbers of this obnoxious insect, whose fecundity is so prodigious; but, after all the schemes that have been propounded for its destruction, it seems evident that we must look to Nature's own checks, aided by any encouragement or protection that we may be able to give to Aphis-devouring creatures. Foremost amongst these come the numerous species of *Coccinella* (Ladybird), the food of which consists almost exclusively of Aphides. Their marvellous voracity is shown equally in their larval and winged condition. In the former stage, the colour is slaty grey or brown, while the body is covered with tufted tubercles, and provided with mandibles, efficient both for holding and sucking out

the juices of the prey, which is seized by the back, and the liquid contents quietly sucked out, the whole process requiring about a minute. Ladybirds, if discovered clustered in crannies, in winter—and they sometimes collect many thousands together—should on no account be destroyed.

Some of the most familiar and the most beautifully coloured flies of our summer belong to the family *Syrphidæ*, which, from the peculiar character of their hovering, darting flight, have been popularly called "Hoverers," and the larvæ of several species of these devout Aphides in immense numbers. These creatures are legless, blind, and leech-like in form, and move slowly, by means of hooklets, with which the posterior rings of their bodies are furnished. The maggot, after each advance, makes a lashing motion with its head, in search of food, and, when an Aphis is struck, it is taken off its legs, and hoisted into the air, where its juices are extracted, and the skin rejected. The eggs of these flies may often be found deposited in the midst of Aphides, multiplying to provide food for the larva at the time of its hatching.

The beautiful Lacewing flies, whose green bodies, delicate wings, and golden or red-tinsel eyes, are so universally admired, are, in the larval state, great enemies to Aphides. When fully fed, the larvæ attach themselves to leaves or stems, and change into short, oval pupæ, hanging head downwards. Amongst the smaller *Hymenoptera* are found very many most useful destroyers of Aphides—*e.g.*, the *Cynipidæ*, although usually regarded as injurious to many plants, as gall makers are, in some of their species, serviceable,

depositing eggs in the Aphis of the rose, the parsnip, the willow, the plum, the peach, and many others. We may also reckon as allies many tiny Ichneumon flies, which persistently attack Aphides not much smaller than themselves. The female deposits from one to five eggs within the body of the Aphis. The resulting grubs live on the food assimilated by the host, whose vital organs, with much consideration, they do not invade until the last moment. His external skin they leave, as this forms a case, within which they pass through their pupal change. *Aphidius Rosæ*, Beckton tells us, he watched "for some time, as two individuals seated themselves upon the backs of Aphides, seeming to enjoy the contortions made to throw them off. After about five minutes, the ovipositor was inserted by a sort of thrust, when the flies made away in pursuit of other game." As the grub within develops, the Aphis visibly undergoes an abnormal modification, the skin at last hardening into a globular, horny box, within which the perfect parasitic Ichneumon is formed, and at last escapes by carving a circular hole. These cases, pierced and empty, may constantly be seen under rose leaves. Curiously enough, the above-mentioned changes are often interrupted by a second parasitic attack, another egg or eggs being deposited within the first parasitic larva, so that it, in turn, succumbs, and another form of life presents itself. How endless the interchanges of life and death; respecting which the philosopher is not much in advance of the humorist, who says—

"Larger fleas have lesser fleas upon their backs to bite 'em,
And these, again, have smaller fleas, and so *ad infinitum*."

CHAPTER XVI.

BEEES AS FERTILISERS, FLORISTS, AND FRUIT-PRODUCERS.

Method of Study — Tropæolum majus — Anthers : Movements of — Colour Streaks on Petals : their Uses — Delphinium — Scrophularia nodosa — Water Ejected by Bees — Epilobium angustifolium — Kalmia latifolia — Poisonous Honey — The Retreat of the Ten Thousand — Heather — Erica tetralix — Calluna — Erica Unedo — Berberis — Dimorphism — Primula veris — Linum grandiflorum — Trimorphism — Lythrum salicaria — Order Compositæ — Cineraria — Flowers Sleeping — Papilionaceous Blossoms — Clovers — Effects of Netting — Lamium album — Salvia officinalis — Fertilisation of Orchis mascula — Bees as Florists — Conjugation the Door of Progress — Bees as Fruit-producers — Apples, Raspberries, Blackberries, Strawberries — Hints on Culture — Conclusion.

WE are now in a position to examine the modifications in form and arrangement of the several parts of flowers, in order to grasp their meaning in relation to fertilisation by insect agency. Since some of the most beautiful aspects of this highly poetical page of the

book of Nature depend upon proportion and interfitting by mutual accommodation, we should be making the greatest mistake if we confined our attention *solely* to the insect which has been the central object of our investigation; as well might we endeavour to realise the beauties of melody by the perpetual sounding of the key note, or to get harmony and contrast in colour by banishing all but one. Our bee, nevertheless, will claim as its right the principal part of our attention, and it will be *its* work, rather than the botanical position of the flower visited, that will determine our arrangement. Many of the orders, standing widely separate in systems of classification, have points in common in relation to their insect fertilisers, and such may, in consequence, stand side by side.

Very many flowers, in which both anther and pistil are found, prevent self-fertilisation by maturing one before the other; and, in the greater number of cases, the anthers ripen first, such blossoms being called proterandrous. Since we have already examined the pelargonium, which is itself proterandrous, let us turn our attention to the *Tropæolum majus* (A and B, Fig. 55), the common garden nasturtium, closely resembling the pelargonium, and a member of the same order. Here, as before, the nectar is contained in a long spur (the nectary, *n*, A), so long as to make the flower more useful to humble than to hive bees. When the flower first opens, the style is short, and the stigma immature and unreceptive; the anthers, also (*a*, *a*, A), are quite unripe, but soon one or two, as seen in the Figure, begin to rise from their first position beneath the flower, by an alteration

in the filament, until they stand just over the stigma, so that a bee, entering, could not fail to get dusted on the breast with pollen (now beginning to be shed), as the tongue is stretched out, and the head pushed forward to reach the sweet secretion in the spur. The anthers, continuing to reach maturity, follow their leaders, one by one, and, during the time that their pollen is being liberated by *dehiscence* (gaping of the pollen pouches), they stand in front of, or close



FIG. 55.—FLOWERS OF *TROPAEOLUM MAJUS* (GARDEN NASTURTIUM),
Order *Geraniaceae* (Natural Size).

A, Young Flower (part removed)—*a, a*, Anthers; *s*, Stigma; *h*, Hairs to save Nectar from Rain; *n*, Nectary, or Spur. B, Older Flower—*a'*, Withered Anthers; *s'*, Receptive Stigma; *h'*, Hairs; *n'*, Nectary.

to, the stigma. This process occupies from three to seven days, during which time the flower is, in function, male only, although, as carrying both anther and pistil, it would be classed as hermaphrodite, or of double gender. The anthers now begin to drop off, the first to mature being, of course, the first to fade, and the filaments which bore them, and carried them into position, now shrivel somewhat, and droop, occupying the position shown at *a'*, B. But the style, mean-

while, has grown longer, and the pistil, now adhesive and receptive, assumes the position, in relation to the rest of the blossom, which the anthers have successively occupied. A bee flitting from flower to flower, loading her legs with pollen, and her honey sac with nectar, passes, with a well-powdered breast, from the younger condition (A) to the older (B), and of necessity presses the pollen grains she carries on to the upstanding stigma, and cross-fertilisation is accomplished—the only possible fertilisation, since the two genders do not co-exist, the blossoms, during their latter period, being exclusively female.

It is well deserving of notice, that the three lower petals (one of which has been removed in the Figure) have their edges cut into a number of narrow strips (*h*), which are turned so as to stand nearly upright. These refuse contact with water, and perfectly protect the nectar from dilution by rain, as may be easily seen by sprinkling water heavily upon one of the blossoms; but they also appear to serve another purpose, in compelling the visiting insect to keep its thorax sufficiently up to bring its hairs on to the stigma. Looking at the blossom now in the front, we observe that the lines on the several petals, according to a beautiful and general law in the floral world, point to the cavity in which the nectar lies, so that these decorations, enhancing the flower so much in the estimation of the florist, are, really, so to speak, guide-posts to the insect visitor.

The sequential movements of the anthers of the tropæolum are common to many blossoms, and the explanation now given will make the delphinium

(larkspur) intelligible, although this belongs to a distinct order—the *Ranunculaceæ*. Here, as in the tropæolum, the five sepals forming the calyx are brightly coloured, while the upper one is produced into a long spur; but, in this case, the two upper petals are continued backwards into the spur, and secrete nectar.

The narrow mouth of the flower is surrounded on all sides by the petals, but these are so shaped, that the tube they form has an opening beneath, just behind the entrance. The tongue of the bee, in stretching towards the nectary, passes, with the head or thorax, over this opening, into which the anthers, as they commence to shed pollen, rise, two or three together, from their position beneath, and so effectually powder the insect on the under side. The anthers drop again when their fertilising dust is exhausted, to be replaced by others until the last, when the pistil becomes receptive, and occupies the spot from which the male organs have retired, thus securing, as before, cross-fertilisation by pollen from a younger blossom. To return to our pelargonium (Plate VIII.). We find this also proterandrous. The anthers (*a*, F) split, and shed their pollen, while the style as yet presents no stigmatic faces, for the former is now like a simple rod; but, when the pollen has wholly or partly disappeared, the upper end of the style divides by longitudinal cleavages, and rolls back into view the five stigmatic, papillose surfaces which had previously been mutually protected from possible contact with pollen. An inspection of a few pelargoniums in a greenhouse will make these several conditions absolutely clear.

The order of development noticed in the blossoms just passed in review is sometimes, though far less commonly, reversed, as in the *Scrophularia nodosa*, or knotted figwort, which, though a most uninviting plant to the florist, has the charm of solid worth to the bee-keeper, for, as nectar-producers, its blossoms, in spite of their ugliness, are hardly to be excelled. The plant is a strong grower, and loves moist situations, where it often attains 6ft. in height, and from June to October bears, on its square stalks, repeatedly-

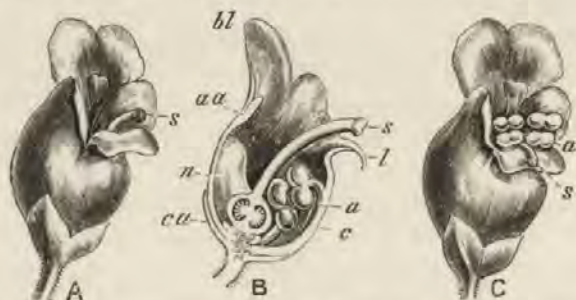


FIG. 56.—SCROPHULARIA NODOSA (KNOTTED FIGWORT), Order *Scrophulariaceæ*.

A, Young Blossom—*s*, Stigma. B, Section of Blossom—*ca*, Calyx; *c*, Corolla; *aa*, Aborted Anther; *s*, Stigma; *l*, Lip; *a*, Anthers; *n*, Nectar; *bl*, Back Lip. C, Older Blossom—*s*, Drooping Stigma; *a*, Anthers.

forked panicles of flowers. These are somewhat globular, and very small, not generally exceeding the size of a pea. Their colour is a dull purplish brown on the upper petal, passing into a russet green beneath.

The flower is hermaphrodite, but, as before, the two genders are never actively co-existent. In this case the stigma is first mature, so that the name proterogynous (meaning first female) is

given. When the corolla opens, the stigma (*s*, A, Fig. 56), already adhesive and receptive, presents itself immediately over the front lip, and bees—having been dusted by pollen in their visits to older flowers, and in a manner we shall presently see—as they reach in after the abundant nectar (*n*, B), transfer this pollen from their hairy breasts to the sticky stigmatic face. Cross-fertilisation having been secured, the stigma shrinks and dries, and the style droops (*s*, C), while the anthers (*a*, B), which previously had been hiding, in a manner which almost looks like humour, in the pouch-like form given to the front of the corolla cup for their accommodation in their moments of bashfulness, now rise into view, take the place whence the stigma has retired, and begin to shed their pollen. How singular that the anthers (*a*, C) should completely occupy the space over the lip, arranging themselves in two pairs, so that, in getting the nectar, the bees must reach across them, if the flower is approached in front; while the height of the back lip (*bl*, B) is such, that it is impracticable for them to steal the honey from behind; and, again, that the fifth anther (*aa*) is aborted, yielding no pollen, because it normally stands at the back of the flower, from which spot the pollen evidently could not be utilised. As the fertilising dust is carried off for the benefit of the younger sister blossoms, the yield of nectar slackens, and the corolla cup at last drops; but it does not do so until the flower has gratefully given for others the equivalent of that which it had itself received. The amount of nectar (*n*) produced is immense, literally filling the lower part of the corolla,

and often standing much higher than in the illustration. Some years since, this plant was called in America Simpson's Honey Plant, and, in a paper extolling its virtues, a bee was drolly represented as flying aloft, singing, "Oh, for a thousand tongues!" Mr. A. Root says that, watching bees at work upon it, he saw the nectar actually distilling into a blossom which, just before, a bee had sucked dry, and that, in less than a minute, a little bead had been formed. He states that, as the bees worked, taking up this thin secretion, they, even whilst humming from flower to flower, discharged watery fluid; his opinion being, that by this process "they make clear, crystal honey from the sweetened water, as it were," that is exuding so constantly from the nectaries of these little flowers. This observation of Mr. Root is quite according to the experience of myself and others. The Malpighian tubes (page 61), acting as kidneys, excrete rapidly any excess of water, but the manner in which the latter passes from the honey sac is not yet clearly explained.

The honey from *scrophularia* is only of medium quality, and it may be urged against the plant that its appearance is not decorative, and the exposed position of the nectar, which permits short-tongued insects to reach it, gives too much encouragement to wasps and their allies; but all bee-keepers, notwithstanding, would do well to sprinkle its seeds in waste places.

Nature's fertility of resources is boundless, and the plan of making hermaphrodite flowers practically unisexual, by bringing the male and female organs to maturity at different periods, is often compounded

with other devices, of which we have an example in the excellent honey-plant, *Epilobium angustifolium* (C, Fig. 57), or rosebay willow herb, belonging to the order *Onagraceæ*. It is by no means so generally seen in England as in Scotland, although it abounds in many parts of Somersetshire. It is common throughout the cooler parts of the Northern hemisphere, and is used in Kamtschatka as forming part of a fermented drink. It grows to the height of 5ft. or 6ft., and is loaded with racemes, carrying great numbers of blossoms, which mature in succession during several weeks. In soils which agree with it, this plant is even more easily established than removed, as it creeps along rapidly by lateral shoots. The wild plants have lilac or pink blossoms, with a lavender-coloured corolla, and bluish pollen; but there are three or four varieties better suited to garden cultivation, of which, *album*, *roseum* and *rosmarinifolium* are to be preferred. The last is really a beautiful plant, and would grace any shrubbery. Some roots were sent me, through the kindness of Mr. Ingram, well-known for the interest he takes in bee botany; they flourished, and, during fair weather, the flowers were always crowded with bees. In the Botanical Gardens, Kew, this plant is grown in the herbaceous grounds, with a multitude of others, and hive bees are generally found about it in numbers. It receives its name from the flowers being placed upon, or at the end of, the pod, which might almost be taken for the stalk; but its interest now centres upon its method of fertilisation. When the flowers open, the style curves backward, carrying the stigma (*s*) to the position shown at A, Fig. 57.

The eight anthers now begin to shed pollen, which bees industriously gather. In two or three days when the anthers have exhausted themselves, the



FIG. 57.—EPILOBIUM ANGUSTIFOLIUM (ROSEBAY WILLOW HERB), Order *Onagraceæ*.

A, Young Flower—*a*, Stigma turned back; *a*, Anthers; *l*, Lobe, or Pod.
 B, Older Flower—*s*, Stigma, turned forward; *a*, Anthers; *l*, Lobe. C, Spike of Flowers. D, Section of Pollen Grain—*e*, Extine; *i*, Intine; *ti*, Thick Intine; *f*, Fovilla. E, Growing Point of Pollen Grain—*e*, Extine; *i*, Intine; *ti*, Thick Intine; *f*, Fovilla; *pt*, Pollen Tube.

style straightens, lengthens to its full dimensions, and spreads its four stigmas (which previously had

been shut up together), in the very position to be pollinated by a bee coming from a younger flower. The pollen grains (D) demand some little attention. These are filled with granular particles—the fovilla of the older botanists—and at the angles the intine is much thickened, which, as before explained, forms the covering membrane for the pollen tube (*pt*, E).

We now turn our attention to a plant yielding a nectar which has qualities poisonous to human beings, although it does not seem to be injurious to the bees themselves. It is a relative of the rhododendrons and azaleas—of bad repute also, so far as honey is concerned, although in the same natural order (*Ericaceæ*) we find our invaluable heathers, whose luscious product is so highly esteemed. I refer to the beautiful *Kalmia latifolia* (A, Fig. 58), selected both on account of its peculiar adaptations to insect visits, and because all apiculturists should know it as a plant to be avoided. It is a native of North America, growing in damp places, over very large areas, and is here well known as a shrubby plant of great attractiveness, bearing pink flowers, with the structure of which every lover of Nature should make himself acquainted. If a flower-bud be cut across, the ten anthers will be found to have their ends tucked into small cavities, or pockets (*ap*, D), which appear as bosses on the outside of the bud, while the filament lies almost in contact with the corolla; but, as the latter expands (B), the filaments are bent outwards and backwards, and so brought into a condition of strain. Now, any sudden jar or rough handling liberates the anther, when the elasticity of its filament suddenly throws it up (as at *a*, C) towards the

style, and the pollen (*pg*) will escape by two pores (*po*, E), and so possibly produce self-fertilisation. But should a bee circle on the wing over the flower, the legs or under side of the abdomen would *first* touch the stigma, and, did the visitor carry pollen, crossing would be the result. The tongue, now feeling



FIG. 58.—*KALMIA LATIFOLIA*, Order *Ericacea*.

- A, Flowering Branch. B, Expanded Flower—*ap*, Anther Pockets. C, Section of Expanded Flower—*ap*, *ap*, Anther Pockets; *s*, Stigma; *a*, Anther (free); *pg*, Pollen Grains in Shower; *ca*, Calyx. D, Section of Flower Bud—*ap*, Anther Pocket. E, Stamen More Enlarged—*a*, Anther; *po*, Pores; *pg*, Pollen Grains; *f*, Filament.

its way into the base of the flower, to secure nectar, would certainly liberate one or more of the anthers, which, projecting their pollen towards the insect, would furnish it with material for fertilising some other blossom. Thus, then, it is that the pollen of one is carried to the stigma of another. Those un-

acquainted with the kalmia would be greatly interested in liberating the anthers by means of a bristle.

During the celebrated retreat of the Ten Thousand, as recorded by Xenophon in his "Anabasis," the soldiers regaled themselves upon some honey which they found near Trebizonde, where were many beehives. Intoxication, with vomiting, was the result. Some were so overcome, he states, as to be incapable of standing. Not a soldier died, but very many were greatly weakened for several days. Tournefort endeavoured to discover whether this account was corroborated by anything ascertainable in the locality, and had good reason to be satisfied respecting it. He concluded that the honey had been gathered from a shrub growing in the neighbourhood of Trebizonde, which is there well known as producing the before-mentioned effects. It is now agreed, that the plants were species of rhododendrons and azaleas. Lamberti confirms Xenophon's account, by stating that similar effects are produced by the honey of Colchis, where the same shrubs are common. In 1790, even, fatal cases occurred in America, in consequence of eating wild honey, which was traced to the *Kalmia latifolia* by an inquiry instituted under the direction of the American Government. Happily, our American cousins are now never likely to thus suffer, thanks to drainage, the plough, and the bee-farm.

The beautiful purple heathers of our moorland and semi-mountain scenery have often given inspiration to the poet, and lovely indeed are the glowing tints the countless bells impart to the landscape, as they reflect the light of the setting sun; but while they

thus in mass charm the artist, one can stir emotion in the breast of the true naturalist. Let us examine the *Erica Tetralix* (the cross-leaved heath), which, though less helpful to the bee than the common ling (*Erica vulgaris*, or *Calluna*), is very similar to it in structure. This species, during July and August, in the southern parts of England, produces abundance of drooping, wax-like flowers, nearly white at the

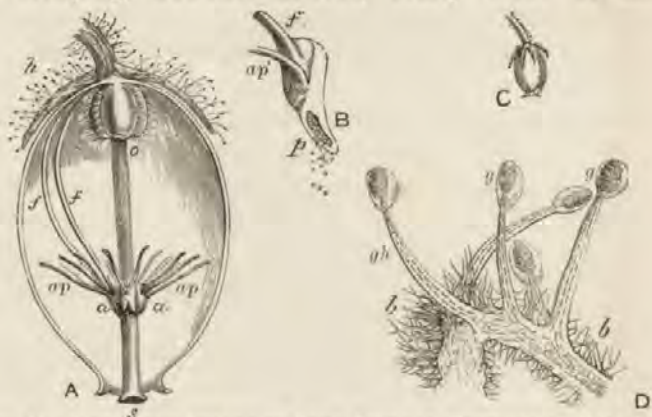


FIG. 59.—FLOWER AND DETAILS OF *ERICA TETRALIX* (CROSS-LEAVED HEATH),
Order *Ericaceae*.

A, Section of Blossom (Magnified Five times)—*a, a*, Anthers; *ap, ap*, Appendages of Anthers; *f, f*, Filaments; *o*, Ovary; *s*, Stigma; *h*, Sticky Hairs. B, Anther—*f*, Filament; *ap*, Part of Appendage of Anther; *p*, Pore of Anther, with Pollen Grains Escaping. C, Blossom (Natural Size). D, Fragment of the Calyx (Magnified Twenty-five times)—*b, b*, Simple Hairs; *gh*, Glandular Hairs; *g, g*, Glands surrounded by Secretion.

base, and delicately shaded with a rich pink. It is certainly the most beautiful of our common indigenous heaths, and grows freely on moist, mossy ground and bogland throughout the kingdom. Opening the bell, which sways in the wind mouth downwards, we find a straight, pinkish style, terminated by the stigma (*s*, A, Fig. 59), hanging in the centre

like a clapper, the stigmatic face in large part closing the narrow opening. The filaments (f, f), eight in number (all but two are removed in the Figure, to avoid confusion), start from the base of the ovary (o), where the nectar is secreted. These filaments, like those of *kalmia*, act as springs, but, in this case, their function is to hold the anther close against the rod-like style. The anthers, also, are provided with oval openings, or pores (p, B), which are placed at their lower ends; but since they are held side by side, in a circle around the style, the pore of one is opposite to the pore of the next, so that the escape of pollen is prevented. Each anther consists of two cells, and each of these is furnished with a horn-like process (ap, A), expressly intended to be in the way of the tongue of the nectar-gatherer. She arrives, but the opening is too small to admit her head, and the distance from the mouth of the bell to the sweets sought is as far as she can reach, so her head is brought up into contact with the viscid stigma. Here she leaves her load of pollen (for she wears hair powder, as we shall see, while she is at work on heather), and so accomplishes her work as fertiliser. The tongue, as it runs up, must strike one or more of the sixteen anther appendages, which act like levers, and so disarrange some of the anthers themselves, and separate their pores, when down rains the fertilising dust upon the bee's little brow (where it remains, as it is beyond the reach of her leg-brushes, so that she *gathers* no pollen from heather). She sucks her nectar, and passes to the next blossom; the elastic filaments restoring the anthers to order, and

awaiting another visit; and the bee applies, almost as quickly, the pollen she carries, to the receptive stigma of the next bell. How clear it is, that some correlation in size between bee and flower is needed! Tiny insects might creep into the bell, and, passing up its sides, secure its nectar, without touching the anther appendages; but if they did, *they* would not be dusted, the pollen would be but wasted, and, worse, the nectar would be gone, and the bee would not be encouraged. A singular device prevents this: the plant, especially about the flower stalks, bracts, and calyx, is covered by glandular hairs, or trichomes (*h*, *A*, and *gh*, *D*), which constantly yield a viscid body, that would stick fast the little thieves if they ventured to attempt to make themselves guests without an invitation. These clammy hairs, however, trouble not the bee: she grasps the glossy bell with her legs, and does not touch the calyx. Her weight but makes the position of the flower the better for the proper placing of the pollen. In the *calluna* (the ling), the flowers are more horizontal, and the style curves upwards, so that the bee's tongue is inserted beneath it; but the whole plan of action is similar to that occurring in *Erica Tetralix* or *E. cinerea*. The sticky hairs, however, are not present, while both the latter species possess them—and why? The mouth of the blossom is so small that it is its own protection. The window need not be shut if its opening is covered by narrow bars, and Nature does not waste force in defending that which needs no defender.

I was greatly pleased, some time since, in studying the blossom of the *Arbutus Unedo* (strawberry tree),

and, although the flower is not *especially* interesting to bee-keepers, I venture to give my results, as illustrating and explaining much that has already been said. This tree-like shrub belongs to the same order as the foregoing, and is characterised by bearing a berry containing many seeds; and its resemblance to the well-known fruit gives the popular name. It is a native of Southern Europe, but with us it is a hardy

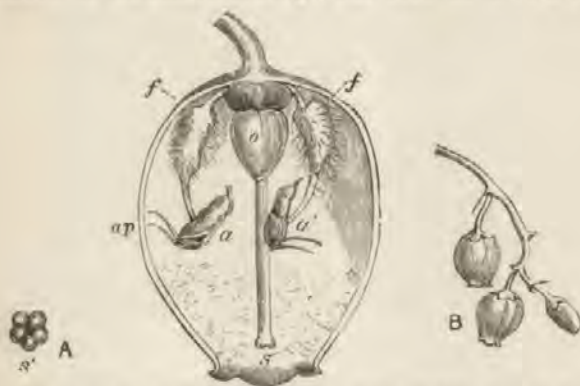


FIG. 60.—FLOWER AND DETAILS OF *ARBUTUS UNEDO* (STRAWBERRY TREE),
Order *Ericaceae*.

A, Section through Blossom (Magnified Five times)—*f, f*, Filaments of Anthers; *a*, Anther driven from Style; *a'*, Anther in Natural Position; *ap*, Appendage of Anther; *s*, Stigma; *o*, Ovary. B, Blossoms (Natural Size). *s'*, The Five Stigmatic Faces communicating with the Five-celled Ovary, more Magnified.

evergreen, reaching 16ft. high, or even more. Its blossoms are greenish-yellow, and are formed in October and November, and, with the same general plan of structure as those just noticed, it has some most singular differences and modifications. We find here ten anthers, placed around a straight style, by spring-like filaments; but the former are disposed in two rows of five each. The inner has its pores placed on the

end, instead of the side, of the cell, so that the style itself stops the orifices; upon the backs of the inner anthers the outer row is pressed, and thus a ring of twenty appendages (*ap*, A, Fig. 60) is set round the centre of the flower. The stigma is receptive before the anthers are ripe. Unless insects quickly visit the blossom, the outer anthers drop back, as at *a*, A; but all the pollen does not at once run out, for the anther is lobed within, and is delicately poised at the back, by a very slender termination to the filament. The pollen which falls is here held by the inner hairs of the corolla (shown in the Figure), and may be swept up by bees' tongues. The second set of anthers (*a'*), at a later period, fall back, and sprinkle their pollen as the others. The suggestion seems to be, that, if bees do not come, then smaller insects, walking up the corolla inside, may get coated, and so fertilise other blossoms (for we must remember that these flowers are proterandrous) by walking down their styles. For it is singular that, notwithstanding the large mouths of the corolla, no sticky hairs occur; but their office is, in this case, performed by the filaments (*f*), which are enormously thickened, and covered with thin, cottony hairs, so that the ten so fill the upper part of the bell, that very small insects could not force their way through them to get the nectar.

It is in this useful order that we find also the cranberry, bilberry, and whortleberry, all the blossoms of which could be well made out by applying the above explanations as an examination might warrant.

The consideration of the movements of the filaments of *Kalmia* and *Arbutus Unedo* naturally introduces a common British plant, whose filaments are remarkably irritable, and hence often secure crossing. In the common barberry, which, in June, bears drooping racemes of yellow flowers, the six filaments spread directly outwards, standing just over the six petals, which bear twelve conspicuous honey glands that are very alluring to bees. Should one of the latter, in seeking sweets, touch a filament, it immediately springs upwards, striking the insect, so as not only to dust its body, but to so startle it that it retires to another flower, when the pollen carried off is immediately transferred to the receptive edge of the upstanding stigma. So persistent is this curious property, that the filament will contract upon being touched after its removal from the flower.

We have previously noticed several cases in which the genders appear on different (*diœcious*) plants, the flowers being unisexual, and, in consequence, incapable of self-fertilisation; and we have now to consider a most interesting set of variations, in which the flowers become practically diœcious, although they remain hermaphrodite, securing cross-fertilisation by differentiating into two, or even three, distinct forms, which are complementary to one another. If, by example, a handful of primroses be gathered promiscuously from *several* plants, they will be found, upon examination, to present very apparent dissimilarities amongst themselves, some having a pale green, almost globular form (*s*, A, Fig. 61), the stigma, at the top of the corolla tube, others, at the same spot,

showing five anthers (a' , B), nearly closing the mouth. Upon splitting these two forms, the first will present an enlargement in the centre of the corolla tube, and here the anthers (a , A) take their position. The second has an enlargement at the top, where the anthers (a' , B) are placed, while the centre of the tube is destitute of any widening, but contains the greenish stigma (s'). It is clear that, if a bee, probably a Humble, visits the first blossom (A), the

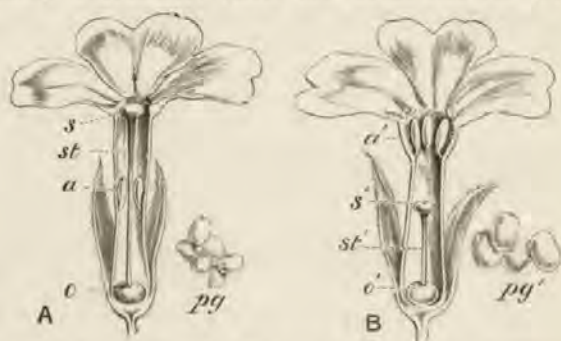


FIG. 61.—CROSS SECTIONS OF DIMORPHIC FLOWER (*PRIMULA VULGARIS*, COMMON PRIMROSE), Order *Primulaceae*.

A, Long-styled Flower— s , Stigma; st , Style; a , Anther; o , Ovary; pg , Pollen Grains, more Magnified. B, Short-styled Form— a' , Anther; s' , Stigma; st' , Style; o' , Ovary; pg' , Pollen Grains, more Magnified.

long tongue, fully outstretched to get at the nectar, will be coated with pollen upon the centre of its length; and should the bee now pass to the second form, the carried pollen will be in the correct position for fertilising the flower, while the tongue will get coated at the root, for subsequently pollinating the first form. Darwin, in a series of admirable experiments, proved that, although seed *might* be produced artificially in the plant under consideration, by

putting pollen from form A upon the same or another flower of form A, that the best seed, and the largest number per capsule, could only be obtained by crossing, not only two flowers, but also the two forms, which are naturally bound together by mutual dependence. This leads to the inquiry, Does any ascertainable difference exist between these pollens? Microscopic measurements show that the pollen grains of form A (*pg*) only contain about one-third the material of those of B, seeming to indicate, although Darwin hazards no opinion here, that the larger grain is best suited to forming the longer pollen tube required in the long-styled form. By further experiment, the existence of that which is commonly called prepotency was proved—*i.e.*, pollen placed on the stigma of the flower form whence it had been derived, would be rendered powerless by subsequently adding pollen from the complementary blossom.

Dimorphism (or double form) is more common than even botanists, not long since, suspected, and amongst dimorphic plants we find those of the highest utility to the bee, because to many such the bee, or some other insect, is a *sine quâ non*. In the *Linaceæ*, or flax family, *e.g.*, certain species are only capable of producing seed *at all* when intercrossed. In *Linum grandiflorum* (A, Fig. 62), the stigmas (*s, s*) and anthers (*a, a*) are so placed, that intercrossing must be generally brought about by bees reaching after the nectar secreted, at five points, at the outside of the anther bases; and experiment has fully shown, that if the pollen of B be placed on its stigmas, or those of any other similarly formed flower, not only is fertilisation not

effected, but the pollen utterly fails in even forming a pollen tube. The pretty *Pulmonaria officinalis*, or lungwort, presents another example of the same singular fact, which obtains, in a less degree, with many other plants; Darwin, in one list, enumerating thirty-four. *Polygonum fagopyrum* (buckwheat), previously figured, is strongly dimorphic, having short styles and long filaments, or the converse.



FIG. 62.—*LINUM GRANDIFLORUM*, Order *Linaceæ*.

A, Blossom and Bud. B, Androecium and Gynoecium of Long-styled Form—*a*, *a*, Anthers; *s*, *s*, Stigmas. C, Androecium and Gynoecium of Short-styled Form; Lettering as before.

But plants occasionally, as previously hinted, present three forms in the same species. No example is more surprising than that of purple loosestrife (*Lythrum Salicaria*), which, withal, is a good honey-producer, secreting nectar all round the base of the ovaries, and, in consequence, visited with great frequency by hive bees. It is also amongst the most handsome of our

native perennials, with its long, tapering spikes of crimson and purple, borne on stems 3ft. or 4ft. high, and decorating gaily the banks of the stream, where it holds its own amongst the sedges, rushes, and willows. Although a water lover, it may be naturalised in the garden; and I know of no plant likely to afford so much pleasure to the scientific bee-keeper. It has, in all its forms, twelve anthers, arranged in two rows of six, and a centrally placed pistil. But the lengths of the style and filaments in no two forms agree; when the style is short, the stamens are medium and long; when the style is medium, the stamens are short and long; and when the style is long, the stamens are short and medium. The long pistil is fertilised by the long stamens of the other two forms, the medium by the medium, and the short by the short; for, as bees pass from plant to plant (each plant bearing only one form of flower), the pollen finds its proper resting-place by the position given to it by the anther whence it came, for the long, medium, and short stamens touch the bee on different parts of the body, which are subsequently applied to the long, medium, and short-styled stigma respectively. The wonders of this interfitting are too many for description. Even the pollens are truly diverse, and of three kinds, while the filaments are distinct, the long being deeply red, the medium and short white. The anther cells of the long filaments are nearly black, and the pollen grains a brilliant emerald green, while the pollen of the short and medium anthers is yellow. The green pollen grain is large, the yellow pollen of the medium anther smaller, and that of the short anther less again, seem-

ing to indicate, as before, that the pollen grain has its size accommodated to the length of tube it has to produce. The bee-keeper possessing these plants will never lack a source of amusement and instruction both for himself and his friends.

The order *Compositæ*, which embraces no less than about 10,000 species, of which 113 are British, includes very many plants that are of the highest utility to the bee-farmer. The name of the order implies that the flower-head (*capitulum*) really carries many blossoms, which, on account of the closeness of their packing, would popularly be regarded as one.

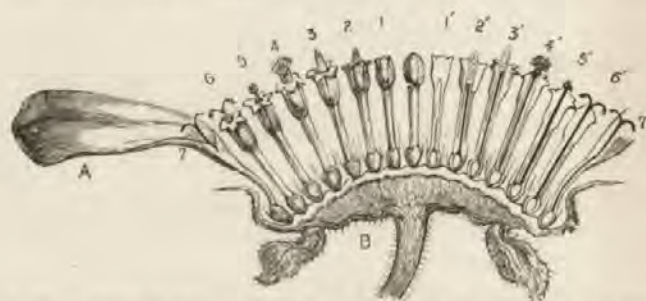


FIG. 65.—SECTION OF FLOWER-HEAD (CAPITULUM) OF COMMON CINERARIA, Order *Compositæ* (Magnified Four times).

A, Ray-floret; B, Receptacle, with Involucre—1, 1', 2, 2', &c., Florets Entire and in Section, in similar Conditions of Development.

Let us first examine a capitulum—and, for our purpose, a sunflower, a field daisy, a thistle, or a golden rod, with its rich nectar, would have answered perfectly; but I choose a cineraria from the greenhouse, for the same reason that I previously selected the pelargonium. Looking at the flower-head, we see a ring of petals surrounding a convex centre,

which careful inspection will show to be formed by the upper ends of a number of tubular flowers. Making a cross section, we find the central flowers, or florets, less developed than those at the side; so that, by passing from the centre to the circumference, we trace the steps of progress through which each floret must pass. In No. 1, Fig. 63, the extension of the corolla tube at its lower end, to accommodate the ovary, is seen, while above, the corolla is just opening. About a day later this floret will have assumed the form of No. 2, where the anthers have grown up partly into view. In this order the anthers and their filaments surround the style, the anthers uniting at their edges, so as to form a tubular sheath, into which the pollen is shed. The style fills the tubular sheath in its lower part, like the rod of a popgun, and, as it grows, drives the pollen before it, until at last the anther tube gives way, and the pollen is pushed out as we see it at Nos. 4, 4', Figs. 63 and 64, when insects, searching for sweets, and collecting or eating the pollen, will get dusted beneath. The style still grows on, and now appears (5) having its end covered with filamentous hairs, which have acted the part of a chimney sweeper's machine in driving the pollen before it. A day or two later, when its fertilising dust has all gone, the style splits, and curves back (6), so as to expose the now receptive stigmatic faces; and thus, as in so many similar cases, crossing is secured. Coming now to the outside floret, carrying one of the rays which make the external ring of the flower-head, we find a distinct alteration. Here the style carries no

brushes, for this floret is purely female, having no anthers. No pollen requires sweeping out, and, therefore, brushes, which could effect no purpose, are not formed; and again, had this floret produced pollen, it could not have been utilised, at least on the same flower-head, since all the florets are proterandrous, the younger in this matter serving the elder, and so absolving the eldest of all from the need of pollen-

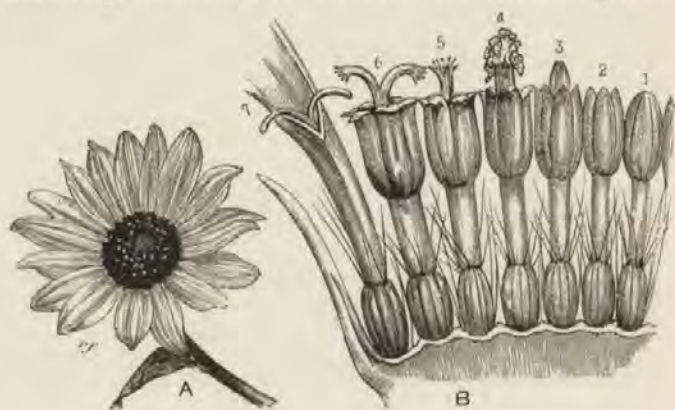


FIG. 64.—A, CAPITULUM OF ONE OF THE COMPOSITE—*cf.* Ray-floret. B, SECTION OF PART OF ONE OF THE COMPOSITE (CINERARIA), Magnified Ten times; Lettering as Fig. 63.

production. Although the plan throughout the order is so similar that the comprehension of one example gives the key to every other, yet there are variations of detail which must be remembered. Thus, in some composite flower-heads every floret bears a ray, as in the dandelion; or all may be tubular and perfect, as in the spear thistle; or the outermost florets neuter, as in the corn bluebottle; or female, as in the case just examined; or monœcious, those of the disk being male,

and the rays female, as in the marigold; or even diœcious, one plant bearing male heads, and another female, as in the cudweed (*Gnaphalium dioicum*).

But all are wonderful; the commonest of composites, the field daisy, peeping out amidst the grass though it forms but little dots in the pattern of Nature's soft carpet, is still a world of wonders in every one of the hundred tiny tubes that make up its little face, with its frill of white and pink. It carries within itself the counterpart of all hitherto explained, with marvel upon marvel beside, to reward him who seeks; for Nature is never truly wooed that she does not lift her veil and smile. The daisy, too, is a sleeper; when the sun goes down, she closes her ray-florets, to open them again when day returns; and hence her name—"day's eye." So with other flowers—the dandelion, the hawkweed, the sandwort, the pimpnel, all of which choose special hours to sleep and wake, adding a day nap when clouds hide the sun. Some blossoms are like *Convolvulus sepium* (the great bindweed), which closes at night, *unless the moon is shining*, and the stillness is broken by the low murmur of the moth's wing, when it remains open. If to this we add, that wind-fertilised blossoms do not sleep, and that those depending on moths are especially fragrant during the most active hours of these nocturnal insects, is not the conclusion almost irresistible, that these peculiarities have relation to the modes of fertilisation of each?

No order contains a larger proportion of plants of utility to bees than the *Leguminosæ*, every British representative of which has an irregular flower, of

papilionaceous (butterfly) form (A, Fig. 65). It is probable, that *all* flowers having an irregular corolla are adapted to fertilisation by insects, and that the latter are prevented, by the irregularity, from reaching the nectary, except from that position which makes their visits effective in securing a cross. In the papilionaceous tribe, it frequently happens, that the nectar-gatherer, in alighting, causes certain mechanical changes by its weight, by means of which pollen is transferred to its body for distribution to neighbouring blossoms. In this order we find lucerne, sainfoin, melilot, clover, vetches, and many others; but the *Pisum sativum* (the kitchen pea), an importation from Southern Europe, is an excellent typical flower, although, singularly, in our own country, failing its native insect attendants, it has acquired the power of self-fertilisation.* The corolla has five petals—a large upper one (*v*), the vexillum, or standard; two that are lateral, the alæ (*a'*), or wings; and two, more or less united at their lower margins, forming the keel, or carina, which, within its boat-shaped cavity incloses the stamens and pistil. The anthers are ten in number; the filaments of nine of them (*a'*, C) are confluent, forming a covering for the ovary beneath and at the sides, but slit above, where the tenth anther (*a*), with its isolated filament, is placed. This slitting gives the bee's tongue access to the nectar at *n*, B and C. The style is somewhat hairy, while the anthers open early, and discharge their pollen, which mainly lodges upon the style. If the blossom of a pea, or vetch, be taken

* Rev. G. Henslow on "Self-fertilisation of Plants" (Transactions of Linnean Society, 2nd Series, vol. i., page 361).

to pieces, it will be seen that the keel petals have each a protuberance, which fits into a corresponding hollow on the inner sides of the alæ, so that the latter cannot be depressed without carrying the keel with them. This is really what happens when the bee settles. The style, forming part of the rigidly set pistil, relatively rises between the keel petals, and touches the bee on the thorax, as at B, leaving

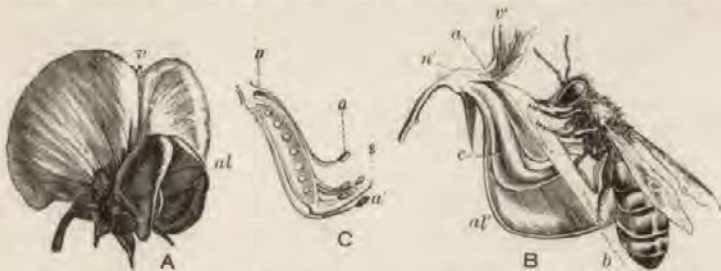


FIG. 65.—PAPILIONACEOUS BLOSSOMS, AND THEIR METHOD OF FERTILISATION.

- A, Expanded Pea Blossom, Order *Leguminosæ*—*v*, Vexillum; *al*, Alæ with Carina between. B, Partial Section of Flower of Vetch being Fertilised by Cyprian Bee (Magnified Twice), Right Ala removed below line *a*, *b*—*v*, Vexillum; *n*, Nectar Gland; *al* Ala; *c*, Carina containing the Pistil, the Stigma of which is striking the Bee's Breast. C, Section of Pistil, showing Ovules (Peas) in Ovary—*n*, Neclary; *a*, *a'*, Anthers; *s*, Stigma.

some pollen, which may be placed on the stigma of the next flower. All this can be easily seen, by holding the blossom steadily, and pushing down the alæ with the fingers. At the departure of the insect, the style again retires, to repeat the process if necessary. The stigma *first* touches the bee's body, so that crossing is brought about; and then, as the tongue is employed in sweeping up the nectar, a new supply of pollen is given; so that, in visiting a succession of blossoms, the pollen of one is transferred to the stigma of the next. The description now given applies to *Lathyrus*

and vetches, but in the scarlet runner a singular and interesting modification must be noticed. The keel is prolonged into a narrow snout, which is literally coiled like a snail's shell, and through which the style, similarly twisted, is prolonged. When a bee visits, the stigma first makes its appearance, and then the pollen-coated style, acting in the manner previously noticed. The French bean has a structure identical with that of the scarlet runner, and both yield honey; yet the latter is sterile without insect action, while the former, where no insect can fertilise it, may be forced, yielding seed in full abundance by self-impregnation. In the melilots and trifoliums, and *Onobrychis* (sainfoin), we have the plants which most gladden the bee-keeper's heart. Their honey is of rare quality, and its amount is astonishing. Their fertilisation is accomplished as before, with slight differences, since the style is not brush-like, but the anthers themselves pass out of the keel to give up their pollen. Darwin points out the utility of bees to these plants. The flowers of *Trifolium incarnatum* (crimson trefoil), which were visited by bees, produced between five and six times as many seeds as those that were protected (covered with a net). Of *Trifolium pratense* (common purple clover), 100 flower-heads on plants protected did not produce a single seed, whilst 100 heads, on plants growing outside, which were visited by bees, yielded 2,720 seeds. In *Trifolium repens* (white Dutch clover), the crossed and self-fertilised plants yielded seeds in the ratio of ten to one; and, in another experiment, twenty heads, unprotected, yielded 2,290 seeds, while twenty pro-

tected heads had "only a single aborted seed." The *Trifolium repens*, taking first rank as a fodder plant, as well as a honey-producer, delights in chalky ground, and often the powdering of lime on the soil will cause a crop of it to appear where previously it had not been cultivated, or known to exist.

The sweet-scented *Labiatae* are not unworthy companions of the *Leguminosæ*, for not a single plant

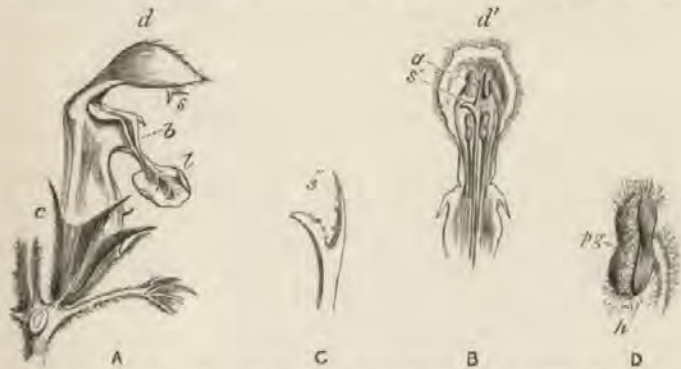


FIG. 66.—FLOWER, &C., OF *LAMIUM ALBUM* (WHITE DEAD NETTLE), Order *Labiatae* (Magnified Twice).

A, Side View of Flower—*c*, Calyx; *l*, Labium, or Lip; *s*, Stigma; *b*, Narrow Mouth to Corolla Tube; *d*, Upper Lip arranged as a Hood. B, Front View of Part of Blossom—*d'*, Upper Lip; *a*, Anthers arranged in Line; *s'*, Stigma. C, Side View of Stigmatic Facies (*s''*) carrying Pollen Grains. D, Enlarged View of Anther dehiscing—*pg*, Pollen Grains; *h*, Hairs holding Pollen Grains.

of the order possesses poisonous properties, whilst amongst them we find lavender, thyme, rosemary, the mints in their varieties, marjoram, sages, sweet basil, savory, balm, germander, horehound, &c., most of which give special aromas to honeys gathered where they abound. *Lamium album* (the white dead nettle), to be found in every hedgerow in the South of England, will make evident the general

characters of the order; but the size of the blossom fits it for fertilisation by Humble bees. The extra size, however, will aid us if we pull a flower to pieces. The nectar is found in the lower portion of the tube, around the ovary, where it can easily be seen by removing the calyx (*c*, A, Fig. 66), and slitting the corolla. This is protected from rain by the umbrella form of the upper lip, which acts more perfectly because it is surrounded by hairs. The tube-like portion of the corolla throws out a broad lip (*l*), which serves as an alighting-place. The flower, in its earlier stage, has the four anthers (for one is aborted, as in *scrophularia*, and for the same reason—see page 285) arranged in line just under the hood, or umbrella (*a*, B), so that, as the bee stretches in after the honey, the central parts of the head and thorax get coated with pollen. We notice another curious adaptation: the anthers are very hairy (D), while they look towards one another, so that, as the fertilising granules leave the anther cells, they are held by the hairs right in the median line. The pollen is now carried away by the bee, to be transferred, in turn, to a more advanced flower, where the stigma (*s''*, C) is both receptive and prominent. Within the corolla, towards the base, we find a ring of hairs pointing upwards, which effectually prevent small insects, whose backs could not be applied to the anthers, from creeping down the tube, and so stealing the nectar.

In several other species of Labiates we have still more singular modifications, cross-fertilisation being secured, as in many previous cases, by the stamens coming to maturity, and shrivelling before the

stigma is receptive; and, in addition, mechanical means are used for placing the pollen on that part of the fertilising insect which alone can be effective. If we take a recently-opened flower of the *Salvia officinalis* (common sage), A, Fig. 67, and make a section, we shall find the stamens are of a most modified character; the filament (*f*, C) is extremely short, and very stiffly set upon a curiously modelled part of the corolla, apparently specially designed to give rigidity (*s*, E). The anther cells, instead of standing at the end of the filament, are widely separated, by a long white rod (*c*, C), the connective, which is itself *hinged* to the top of the filament, while the lower anther cell is aborted, producing no pollen. The nectar is secreted, as in the lamium, at the end of the corolla tube. When the blossom is entire, the two aborted anther cells meet together, and bar the entrance to the flower, at the lower part. A bee, attempting to enter, drives her head against the aborted cells, which immediately yield, and run back into the flower, turning the connectives on each side on their hinges (*hi*, D), at the end of the filaments, by which the anther cells (*a*, C), carrying pollen, are patted down on to the bee's back (*a*, D); and here a dense patch of coloured dust is left. The nectar having been absorbed, the bee departs, and, as its head is withdrawn, the connectives revolve into their old position, and the anthers await another arrival, until all the pollen has gone. While the anthers wither, the style (*st*, C and D), short in the young stage of the flower, grows rapidly, and presently occupies the position seen at B. Our gatherer arrives, decorated on the back, and, pushing

into the corolla mouth, gives up the burden, of which it is unconscious, on to the stigmatic face, now waiting to receive it. If a pencil be passed into the mouth of a flower of *Salvia patens* or *S. fulgens*—both of which, on account of their great length of corolla, are desirable for illustration—the

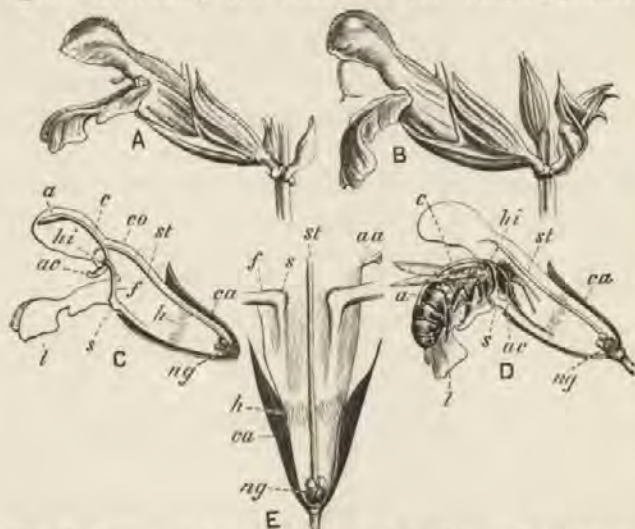


FIG. 57.—BLOSSOM OF *SALVIA OFFICINALIS*, Order *Labiata* (Natural Size).

A, Young Flower, showing aborted Anther Cell. B, Older Flower, showing Stigma. C, Section of Young Flower—*a*, Anther Cell; *ac*, Aborted Cell; *c*, Connective; *f*, Filament; *hi*, Hinge of Filament; *co*, Corolla; *ca*, Calyx; *st*, Style; *s*, Stiff Attachment of Filament; *l*, Labium; *h*, Interior Hairs; *ng*, Nectar Gland. D, Section of Young Flower, with Bee entering; Lettering as before. E, Section of Base of Flower flattened out, Lower Part shown—*st*, Style; *s* and *f*, Stiff Attachment of Filament of Pollen-bearing Anther; *aa*, Aborted Anther; *h*, Interior Hairs; *ca*, Calyx; *ng*, Nectar Gland.

descent of the anther, attached to a connective, perhaps an inch in length, and looking like a mimic chopper, the blow of which decorates the pencil, cannot fail to cause astonishment. Indeed, I can hardly imagine any sight more curious than that pre-

sented, any summer afternoon, in the Herbaceous Garden at Kew, where hundreds of various Labiates, growing side by side, attract crowds of bees, of different genera and varied sizes, which, entering the curious flowers these plants bear so profusely, bring the hiding anthers into view, literally getting patted on the back for their pains. It is only, however, insects of the correct bulk that can effect the work; they must be large enough to meet the anther, and reach up to the stigma; and so, to prevent smaller ones from stealing that abundant nectar intended for their superiors, in size at least, the lobster-pot arrangement, previously noted, is supplied, and seen at *h*, C and E, up to which the nectar frequently extends. But this is not the only manner in which thieves are kept at bay; in a *salvia* common on the Continent (*Salvia glutinosa*), there are no internal hairs, but the flower-spikes, bracts, and the entire outside of the blossom, are covered by secreting trichomes, which are exceedingly sticky, frequently holding as prisoners crowds of small insects, that vainly paw the air, pleading for release. The inside of the flower, including the lip upon which the bees settle, is not adhesive, so that the favoured insect is not incommoded. The plan brings to mind the *Erica Tetralix* (page 294).

In the order *Cruciferae* we have many useful honey plants, embracing the wallflower, stock, cress, rocket, cabbage, turnip, and mustard; the wild form of the latter (charlock, or cadlock), as a widespread weed, yielding, in some districts, the staple of the bee-keeper's harvest. The most usual form of adap-

tation in this order, which is very varied, is one of great interest, and must be ascertained by an inspection of the flowers. The anthers in the young blossoms *face* the style, but before they ripen they turn their backs, and shed the pollen, which is thus in the least likely position to find its way to the stigma of the flower yielding it, but in the most favourable place for adhering to insect visitors acting as cross-fertilisers. The *retorse* anther, as it is called, is frequent in its occurrence in other orders.

Our space has permitted us to deal with types only, and these would be extremely incomplete without some notice of orchids, which have always been objects of wonder, but have never attracted more attention than in recent years, as their investigation has revealed devices which appear to the last degree romantic. The one example chosen for illustration is a British species, *Orchis Morio*, which, as I have several times witnessed, is habitually visited by the hive bee, and so here is of deeper interest than the more extraordinary exotics, many of which are large nectar-producers, while all species of the sixteen British genera are of only moderate value in this respect. The flowers in this order are exceedingly unlike those we have previously studied, so that some little attention must first be given to general structure. In Fig. 68, A, we find, as in all common orchids, but one developed anther (*a*), which has no distinct filament, for this is confluent with the pistils, forming together the column—the part of the flower immediately in front of the bee's head. The anther, which we have seen in other cases to carry the

vivifying element (the pollen), in the form of granules, collected in two cells, has here a peculiar structure: its cells are two, but they are so widely separated (*a', a', C*) as almost to appear like two separate anthers; while the pollen they contain coheres in masses (pollinia, *po*, D), held together by internal elastic

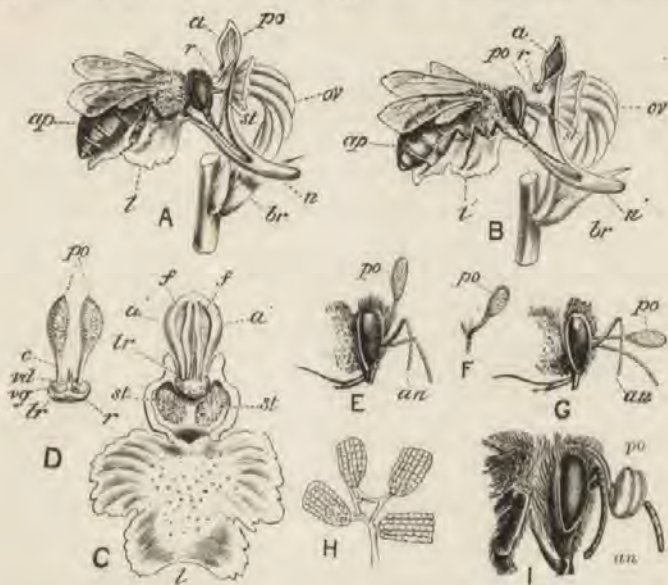


FIG. 68.—ORCHID (Order Orchidaceae) BLOSSOMS AND DETAILS.

A, Flower of *Orchis Morio*, Sepals, two Petals, and side of Spur removed, with *Apis Mellifera* (*ap*), Hive Bee, sucking Nectar—*a*, Anther; *po*, Pollinium or Pollen Mass; *r*, Rostellum; *st*, Stigma (side view); *l*, Labellum; *ov*, Ovary; *n*, Nectary; *br*, Bract. B, Bee fertilising *Orchis Morio*—*a*, Anther with Pollinium removed; *po*, Pollinium, attached to Bee's Head and applied to Stigma; other Letterings as before. C, Front View of *Orchis Morio*, Magnified Three times, Sepals and two Petals removed—*lr*, Lip of Rostellum; *f, f*, Fissures in Front of Anther Cells (*a', a'*); other Letterings as before. D, Pollen Masses, &c.—*po*, Pollinia; *c*, Caudicle; *ed*, Viscid Disc; *vg*, Viscid Globe; *lr*, Lip of (*r*) Rostellum. E, Head of Bee, carrying (*po*) Pollinium—*an*, Antennae. F, Position of—*po*, Pollinia (thirty seconds later), partially depressed. G, Head of Bee—*an*, Antennae; *po*, Pollinia (sixty seconds later) fully depressed. H, Pollen Granules (much magnified), held in packets by thin elastic threads. I, Head of Bee, carrying (*po*) Pollinia of one of the *Vandae*—*an*, Antennae.

threads, which also tie each mass, at the end of a very curious, stalk-like appendage (the caudicle, *c*), which is again attached to a viscid piece of membrane (the viscid disc, *vd*), having below it the viscid globe (*vg*). The method of distributing the pollen will come before us presently. The stigmatic faces are, theoretically, three, but only two are fertilised by pollen, with the formation of pollen tubes, entering the ovary in the usual manner; their sticky faces are seen, side view, at *st*, A; in the front view, *st*, C. The third stigma is modified into what is called the rostellum (*r*, A), which contains the viscid matter of the discs and globes just mentioned, playing a most whimsical function, in order to secure crossing. The outer portions of the flower consist, as in most orders, of calyx and corolla, here divided into three sepals and three petals respectively. All of the former, and two of the latter, have been removed, to permit of an uninterrupted view of the organs of reproduction. The third petal, properly the upper one, but made the lower by a semi-twist of the ovary (*ov*, A), is larger than the others, and offers a landing-place to insects, as we see by the position the bee has taken. It is called the lower lip, or labellum (*l*), and is carried backwards in the form of a spur, where it assumes the functions of a nectary (*n*), and so attracts visitors. The anther cells are longitudinally open in front, the fissures (*f*, *f*, C) of the covering occurring before the flower opens, so that the pollinia may be taken out from their pouches, in which they lie, but to which they are not attached. The membrane, forming the whole external surface of the

rostellum, is at first continuous, but, as soon as the flower opens, the slightest touch causes it to rupture transversely, in a sinuous line (*lr*, C and D) in front of the anther cells. Let us now suppose that a bee (*ap*, A) alights on the labellum, and advances the head, in order that the tongue may reach the nectary (*n*), where the sweet liquid must be secured by an abrasion of the delicate lining membrane. The rostellum, irritated by the touch of the insect, immediately ruptures its covering skin (if this were entire at the previous moment), and the pushing forward of the head depresses its lip (*lr*, D), so that the viscid discs (*vd*), formerly a part of the covering membrane of the rostellum, and the viscid globes (*vg*), are exposed, the latter infallibly coming into contact with some part of the bee's head. So viscid are these globes that they firmly stick to whatever they touch; moreover, they have the property of setting hard in a few seconds. During the time occupied in sucking the nectar, they, in consequence, become firmly attached to the head of the bee, the connected pollen masses still lying in the anther pouches, whence, as we know, they can be readily withdrawn; this is accomplished as our bee retires carrying a decoration in the form of two upstanding yellowish-green horns (*po*, D and E, the pollinia of the orchid). Darwin pointed out that all this may be exactly imitated by a well-pointed pencil, or a stiff bristle; and none would regret the little trouble involved in growing a few common hardy orchids, in order to have the pleasure of showing the experiment to friends. But how are these pollinia to be made

effective? How is their material transferred to the surfaces of the stigmas; for will not the next flower visited have these masses thrust forward towards its own anther pouches? Such *would* be the case with the visits *immediately* succeeding the first. Watching our pencil point, or the head of the bee, the pollinia, at first erect on their caudicles (*po*, E), and firmly secured by the drying of the viscid globes, begin to incline forwards, and continue to move, always in one direction (towards the pencil point), until they have swept through an arc of about 90° , finally standing as at *po*, G; the movement occupying about thirty seconds on an average. Re-inserting our pencil, or our bee making another visit, will now secure fertilisation, because the pollinia immediately strike the stigmatic faces (*st*, C), as we see actually being done at *po*, B. How perfect the adaptation! But where lies the secret of the movement executed? The little viscid disc (*vd*, D) is endued with a power of unequal contraction, and produces the required change in position, the time occupied by it permitting the bee to get from one plant to another, so that the best form of crossing is secured. And yet another adaptation demands attention. The pollinium is very coherent; but the elastic threads holding it together in packets (H) break with the energy the insect can exert, so that *some* pollen is left, and yet a mass carried away, which may be effectively used upon flower after flower, until at last the ragged caudicle alone remains.

Some time since, when I had announced the discovery of some diseases previously not known amongst bees, a bee was sent to me, whose portrait is given at I,

and I was asked to name the disease which had caused an abnormal outgrowth upon its head. It had visited, there can be little doubt, an orchid-house, and had carried away a decoration from one of the *Vandææ*.

The description given above applies to *Orchis mascula*, *fusca*, *maculata*, and *latifolia*, as well as *Aceras anthropophora* (the man orchis), in all of which the pollinia undergo the same curious movements of depression which are necessary to enable them to strike the stigmatic surfaces. The behaviour of these British specimens is quite commonplace, however, in comparison with that of some exotic orchids explained by the genius of Darwin. A few words in reference to one will suffice. In *Catasetum*, the genders are divided, and the male blossom is provided with a strange pair of long additions, called by Darwin "the antennæ." In some species both are equally active, but in others the right one seems functionless, while the left is intensely irritable, and, should an insect touch it, a vibration is transmitted to a certain membrane, which is instantly ruptured, and so sets free the pollen mass, which is shot forth from the extremity of a liberated spring, viscid end first, to attach itself to the back of the insect. The startled bee flies, possibly, to the female flower, and here accomplishes a cross; this act being favoured by the curious habit of the *Apidæ* of visiting one kind of flower only, during any single excursion—a habit for which no sufficient explanation can be given, although it will receive further notice hereafter. Sir John Lubbock says: "On one occasion, Darwin touched a male *catasetum* in my presence, when the pollinium was thrown nearly

3ft., and stuck on the pane of a window." I have seen this droll performance at Kew, and although 3ft. exceeded the distance, the force of the ejection was most remarkable. Are those who assert that Nature knows no humour altogether justified?

The examples so far cited and explained will serve as a guide to those who desire to unravel the secrets of the loves of the flowers. The bee we have seen to play the part of fertiliser, so that upon her action has depended the production of seed in those plants which have lost the power of self-fertilisation; but this is only one aspect of her work, for she, the unconscious instrument, in a Hand unseen, has been made to suffuse the landscape with colour, and strew the path of man with the beauties of the floral world. The homely garb of self-fertilised and anemophilous flowers, such as those of the chickweed, the nettle, and the dock, indicates what all would have been without insect action. In many genera, the species present the greatest diversity with regard to the size and beauty of their blossoms—*e.g.*, *Epilobium angustifolium* has handsome and conspicuous flowers, disposed in dense racemes, and which, being proterandrous, are absolutely dependent. In *Epilobium parviflorum*, or *palustre*, the flowers are small and solitary, while they are capable of setting seed by themselves, for their anthers and stigmas are mature contemporaneously. So with the geranium family, the different species indicating by the sizes of their flowers how far they need insect help: the large *Geranium pratense*, impotent without insects; the small *pusillum*, generally self-fertilised. The reason

is apparent: all variations which render the blossoms more attractive, either by scent, colour, size of corolla, or quantity of nectar, make the insect visit more sure, and therefore the production of seed more likely. Thus, the conspicuous blossoms secure descendants which inherit the special variations of their parents, and so, generation after generation, we have selection in favour of conspicuous flowers, where insects are at work. *Their* appreciation of colour, because it has brought the blossom possessing it more immediately into their view, and more surely under their attention, has enabled them, through the ages, to be preparing the specimens upon which man now operates; he taking up the work where they have left it, selecting, inoculating, and hybridising, according to his own rules of taste, and developing a beauty which insects alone could never have evolved. His are the finishing touches, his the apparent effects; yet no less is it true, that the results of his floriculture would never have been attainable without insect helpers. It is equally certain, that the beautiful perfume, and the nectar also, are, in their present development, the outcome of repeated insect selection; and here, it seems to me, we get an inkling of a deep mystery: Why is life, in all its forms so dependent upon the fusion of *two* individual elements? Is it not, that thus the doorway of progress has been opened? If each *alone* had reproduced, itself all-in-all, advance would have been impossible; the insect and human florists and pomologists, like the improvers of animal races, would have had no platform for their operation, and, not only the forms of life, but life itself,

would have been stereotyped unalterably, ever mechanically giving repetition to identical phenomena.

A new consideration now awaits us: Bees are not only florists—they are fruit-producers; our orchard and fruit crops, and leguminous seeds, constituting together no inconsiderable fraction of human food, are very largely dependent upon insect agency, and the fee paid for professional attendance on the part of the little inoculator is nectar. Let us take, as an example, the apple, a fruit which, from a utilitarian



FIG. 69.—APPLE (*PYRUS MALUS*, Order *Rosaceae*) BLOSSOM, AND SECTION OF FRUIT.

A, Blossom (Natural Size)—*s*, Stigmas; *a*, Anthers; *p*, Petal; *ca*, Calyx; *e*, Sepal; *d*, Dissepiment. B, Section through partly developed Fruit—*f*, *f*, Fertilised Carpels; *u*, Unfertilised ditto.

point of view, has, in this country, no equal. Its pretty blossom carries five stigmas, three of which remain in the section A, Fig. 69; to each stigma belongs a dissepiment, or division, of the compounded ovary constituting the core of the fruit. The stigma comes to maturity before the anthers, as in *Scrophularia nodosa*. Bees seeking nectar get dusted completely, and then transfer the granules to the stigmas of neighbouring blossoms, while they are constantly at work in packing the excess into their corbiculæ.

And here let us remark in a parenthesis that the multitude of pollen granules furnished by entomophilous plants, although usually less than in the case of the anemophilous, is, nevertheless, enormous; the single pæony, *e.g.*, yielding about three and a half millions per flower, while the number of granules actually utilised is measured by the number of the ovules. In the curious cleistogamous flowers produced occasionally or regularly by not a few plants, and which do not open at all, or only in part—as the scentless and small autumnal blossoms of the violet—there is no repast for the insect, of nectar there is none, and not a granule of pollen to spare; for the anthers and stigma, especially the former, are extremely small. Yet self-fertilisation is completed, and seeds are abundantly furnished, for all causes of waste are avoided. But to return.

The apple, as its blossom indicates, is, strictly, a fusion of five fruits into one—hence called pseudosyncarpous—and demands, for its production in perfection, no less than five independent fertilisations. If none are effected, the calyx, which really forms the flesh of the fruit, instead of swelling, dries, and soon drops. An apple often develops, however, though imperfectly, if four only of the stigmas have been pollen dusted, but it rarely hangs long enough to ripen, the first severe storm sending it to the pigs as a windfall. I had 200 apples, that had dropped during a gale, gathered promiscuously for a lecture illustration, and the cause of falling, in every case but eight, was traceable to imperfect fertilisation. These fruits may be generally known by a deformity; one part

has failed to grow, because there has been no diversion of nutrition towards it. Cutting it across with a knife, we find its hollow cheek lies opposite the unfertilised dissepiment (*u*, B), containing only shrivelled pips. Pears are less impatient of imperfect insect action than apples, though the structure of the flower is the same. Amongst small fruits, gooseberries are proterandrous, and absolutely dependent on insects. The failure of this crop is not so uniformly the result, as some suppose, of frost



FIG. 70.—RASPBERRY (*RUBUS IDEUS*, Order *Rosaceæ*) BEING FERTILISED, AND SECTION OF SAME.

A, Flower (Magnified Twice)—*p*, *p*, Petals; *a*, *a*, Anthers; *s*, Stigma; *no*, Nectary Openings; *nc*, Nectar Cells; *D*, Drupels. B, Section through Core, or Torus (C) and Drupels (D)—*ud*, Unfertilised Drupel; *ws*, Withered Stigma; *ua*, Withered Anther.

(this browning the exposed fruits); cold weather at the critical time, keeping bees within, often being the chief cause, and showing itself in the dropping of the open flowers from the protected branches. It is here significant, that currants, which ripen their pistils and anthers simultaneously, are said to be less tender than gooseberries.

The raspberry gives the bee good return for its work by yielding honey of excellent quality, and the whole arrangement of its inflorescence points to an effort to secure crossing. The petals (p, p, A , Fig. 70) are small, and widely placed, while within them are disposed about ninety anthers (a, a), on longer and shorter filaments, which are set back, away from the stigmas (s), one of which is carried by each of the sixty or seventy drupels (D) making up the raspberry. Examining a flower with a hand magnifier, we find a circle of glistening dots (no) upon the receptacle, and between the anthers and drupels. These dots consist of nectar, furnished by secreting cells (nc) beneath. The bee alights upon the only solid resting-place, the drupels, and applies her tongue rapidly to dot after dot, revolving her body during the operation, by which she gets dusted, on one side and beneath, with pollen. Passing to the next blossom, she repeats the operation, commonly with a difference which is of primal importance: she revolves in the *opposite* direction, by which she brings into play new muscles, and rests those of the side which have just been exercised. The result is evident: the pollen acquired on the previous visit is applied to the numerous stigmatic faces waiting to receive it, which, as we have so often seen, again secure crossing. Each seed thus fertilised is soon surrounded by the luscious envelope which protects the seed from injury, and makes the manufacture of raspberry jam a possibility. These rounded, red masses are never formed unless fertilisation has taken place, neither ripening nor growth being possible in its absence. When the season

is closing, the raspberry frequently fails in developing some, or many, of its drupels; they remain green and shrunken, for hive bees are loth to venture abroad, and wild ones are dying off, or seeking, in the case of the females, winter quarters. Some complain that bees eat fruit, a charge which need not be rebutted; but it is for the bee-keeper to proclaim that, while they gather nectar for themselves, and also for the benefit of their master, they confer a *greater* boon on the fruit-grower, for they really give him his crop in return. The flowers of the blackberry (*Rubus fruticosus*) are similar in structure, and the explanation given fully applies to them.

If we look at a strawberry, which is of a similar type to the foregoing, we find a vast number of (popularly) seeds (really *achenia*) studding its surface. Every one of these possessed a style and stigma, as at *s, s, A*, Fig. 71, and has had pollen conveyed to it by the action of insects, bees mainly. When the bee settles, she, in her circular walk, rubs from her body on to the stigmas, pollen brought from another flower, as in the raspberry, for the stigmas are receptive before the anthers have begun to dehisce. The fertilisation, as before, determines nutrition to the part, and the flower-stalk, which forms the strawberry, becomes a luscious parenchyma. But if any stigmas remain unpollinated, no development occurs at that spot, and here the strawberry continues (as at *u, B*) hard, shrunken, and green, even when the fertilised portion is fully ripe. We must all again and again have seen illustrations of this, from which we learn, that every strawberry requires

from 100 to 200, or even 300, distinct fertilisations for its perfect production.

It would be unwise to omit a practical matter in this connection. There is a tendency to a separation of the sexes in the cultivated strawberry, which, Darwin observes, "is far more strongly marked in the United States than in Europe;" and growers would do well to note, that plants bearing unusually large blossoms are frequently tending to become male, and produce few fruits; while those of the same



FIG. 71.—STRAWBERRY (*FRAGARIA VESCA*, Order *Rosacea*), PARTLY AND FULLY GROWN.

A, Strawberry, Earlier Stage—*a*, Anther; *s, s*, Stigmas; *p*, Petal. B, Section of Mature Strawberry—*a'*, Withered Anther; *f*, Fertilised Achenium (popularly Seed); *u*, Unfertilised ditto; *s'*, Withered Stigma.

variety, and under the same treatment, that produce small blossoms, are tending to become female, and are abundant bearers, while they yield few runners. Without care in selecting, the numerous runners of the former would ultimately supplant the female forms, and so ruin the stock for economic purposes. Lecturing, some while since, to several of the largest growers of strawberries in the kingdom, I found all quite unaware of this fact—at least, on its scientific

side—although in my own small beds the differences had been sufficiently conspicuous.

We have yet to apply the numerous facts and natural laws we have considered to Practical Apiculture, which has utilities beyond those generally supposed; and we can now see the wisdom of Girard's remark, that "all money thrown out of the window, in encouraging apiculture, will come in again by the door, with heavy interest." My sketch, which does not cover the ground, but yet, I hope, dots it with illustrations that may illumine the rest, must be regarded as completed. And it leaves us here. The bee, with all its wonderfulness, is only one wheel within many: she takes to truly give, for seeds, flowers, and fruits, follow in her train. Her honey is but a fraction of the results of her labours. Man has had tiny helpers that he knew not of. While he, for seasons, has selected and hybridised, they, for ages, have, with their little powers, toiled along, perpetuating every movement of the world of flowers towards the beautiful. Flowers, yours is equal wonder and equal praise; for dimly through you both I see that the praise is not yours at all, saying with Tennyson:

"Flower in the crannied wall,
I pluck you out of the crannies;—
Hold you here, root and all, in my hand,
Little flower;—but if I could understand
What you are, root and all, and all in all,
I should know what God and man is."

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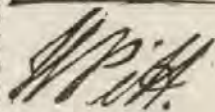


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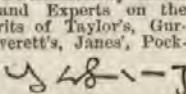
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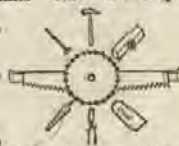
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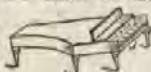
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Thursk, Yorks, January 25, 1876.

DEAR SIR,—I use your Hyperion Hair Restorer, and find it everything which has been said in its favour. I am, dear Sir, yours truly, T. COATES.

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