alternately all round the base of the pyramid, there being three of each kind and six in all. The axis of each cell coincides not with the axis of the cell on the opposite surface, but with one of its angles; so that each of the three obtuse angles at the base of the terminal pyramid corresponds to the central parts of three of the cells on the opposite side, and each of the sides of the pyramid which closes a cell on one side contributes in part to the enclosing of three of the cells on the opposite side. We may easily satisfy ourselves that such is the case by piercing the centres of each of the three planes which close the bottom of a cell with a pin, when on turning the comb the three pins will be found to have passed into three different cells on the opposite side.

A structure of this kind is obviously the one of all others calculated to afford the greatest space for each cell with the same quantity of materials. It is easy to perceive, in the first place, that in a plane surface, when a number of small spaces are to be divided by partitions, the hexagonal form is the one which comprehends the largest space compatible with the extent of the lines which enclose them; for the equilateral triangle, the square, and the regular hexagon, are the only regular forms that admit of being joined together in the same plane without leaving interstices; and the proportion of the area to the periphery in every 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. The truth of this proposition was perceived by Pappus; and even its application to the subject of the honeycomb was made by that ancient geometrician. But the determination of the form and inclination that should be given to the partitions that close the bottom of the cells, and which may, of course, belong equally to those on both sides of the comb, is a problem much more complicated and difficult of solution. It has exercised the skill of several modern mathematicians of great eminence. Reaumur proposed to König, pupil of the celebrated Bernouilli, and an expert analyst, the solution of the problem:—To find the construction of a hexagonal prism terminated by a pyramid composed of three equal and similar rhombs (and the whole of given capacity), such that the solid may be made with the least possible quantity of materials;—which in other words was asking him to determine the angles of the rhombs that should cut the hexagonal prism so as to form with it the figure of the least possible surface, since the hexagon being given, this decided both their dimensions and their intersections with the sides of the cell. Maraldi had previously measured the angles of the rhombus and found them to be 109° 28′ and 70° 32′ respectively; but König was not aware of this until after he had solved the problem, and assigned 109° 26′ and 70° 34′ as the angles, when he had sent him the *Memoirs of the Academy of Science for* 1712, containing Maraldi's paper; and König was equally surprised and pleased to find how nearly the actual measurement agreed with the result of his investigation. The measurement of Maraldi is correct, and the bees have, with rigorous accuracy, solved the problem, for the error turns out to be in König's solution. The construction of cells, then, is demonstrated to be such that no other that could be conceived would take so little material and labour to afford the same room.

Boscovich, who has also given a solution of the same problem, supposes that the equality of inclination of the planes gives greater facility to the construction of the comb, and might, therefore, be a motive of preference, independently of the greater economy of wax. Maclaurin has offered a solution of this problem, and has demonstrated by simple geometry, that the most advantageous form is that which results from the supposed equality of the three plane angles forming the solid angles at the base. He estimates the saving of wax by partition so constructed, above what would be required for a flat partition, at one-fourth of the wax which would be wanted to complete the truncated sides of the cells, so as to form them into rectangles. L'Huillier, in the *Memoirs of the Berlin Academy*, has given a demonstration which is remarkable for its simplicity, and for its involving none but elementary propositions; he values the economy of wax at $\frac{1}{51}$ of the whole wax employed. Le Sage, as appears from the life of that philosopher by Professor Prevost, has shown that this celebrated problem reduces itself to the finding of the angle at which two planes with a given inclination (such as 120°) can be cut by a third plane, so as to make all the angles resulting from the section equal to one another.

But a more essential advantage than even the economy of wax results from this structure, namely, that the whole fabric has much greater strength than if it were composed of planes at right angles to one another; and when we consider the weight they have to support when stored with honey, pollen, and the young brood, besides that of the bees themselves, it is evident that strength is a material requisite in the work.

It has often been a subject of wonder how such diminutive insects could have adopted and adhered to so regular a plan of architecture, and what principles can actuate so great a multitude to co-operate, by the most effectual and systematic mode, in its completion. Buffon has endeavoured to explain the hexagonal form by the uniform pressure of a great number of bees all working at the same time, exerted equally in all directions in a limited space; and illustrates his theory by supposing a number of similar cylinders compressed together, and taking the form of hexagonal prisms by the uniform expansion of each. The analogy of the forms produced by the law of crystallization,—of the figures assumed by various organs in the animal and vegetable world, such as the skin of the bat, and the inner coat of the second stomach of ruminant quadrupeds,—is also adduced by this captivating but superficial writer in support of his argument. But however plausible this theory may at first sight appear, it will not stand the test of a serious examination. The explanation he has attempted applies no further than to the inclination of the sides of the cells; but he did not take into account, perhaps from not having studied the subject mathematically, the inclinations and forms of the planes which close each cell, and so curiously conspire on both sides to serve a similar office, while they at the same time accurately fulfil a refined geometrical condition. But it is sufficient confutation of the whole theory to show, that it is directly at variance with the actual process employed by the insects in the construction of their combs. Buffon's theory of the formation of the combs.

It might be supposed that bees had been provided by nature with instruments for building of a form somewhat analogous to the angles of the cells; but in no part, either of the teeth, antennæ, or feet, can any such correspondence be traced. Their shape in no respect answers to that of the rhombs, which are constructed by their means, any more than the chisel of the sculptor resembles the statue which it has carved. The shape of the head is indeed triangular, but its three angles are acute, and are different from that of the planes of the cells. The form of the plates of wax, as they are moulded in the pouches in which this substance is secreted, is an irregular pentagon, in no respect affording a model for any of the parts which compose the honeycomb. Hunter, observing that the thickness of the partition was nearly equal to that of the scale of wax, thought that the bees apply these scales immediately to the formation of the partition, by merely cementing them together. Reaumur, notwithstanding the use of glass hives, had not been able to discover the mystery of their process

of architecture, but inferred, from what he saw, that the wax was rejected from the stomach in the form of a white frothy liquor. No naturalist, indeed, prior to Huber, had been able to follow these insects in their labours, on account of their crowding together in a thick mass while they are building; but the expedients resorted to by that philosopher have unfolded the whole process, which he has given with great detail in the second volume of his *Observations sur les Abeilles*. Huber witnessed the whole of their actions, and saw that each bee drew out, with its hind feet, one of the plates of wax from under the scale where it was lodged, and carrying it to the mouth in a vertical position, turned it round, so that every part of its edge was made to pass in succession under the cutting edge of the jaws; it was thus soon divided into very small fragments, while at the same time a frothy liquor was poured upon it from the tongue, so as to form it into a perfectly plastic mass. This liquor gave the wax a whiteness and opacity which it did not possess originally, and rendered it at the same time tenacious and ductile. A quantity of wax thus prepared for use is accumulated, and applied to further the work in the manner we are presently to describe.

But, in considering the process by which the comb is formed, a circumstance should be pointed out, which seems not to have been particularly noticed by any author except Huber, and yet it is one of essential importance in studying this process of architecture, namely, that the cells in the outside row on each side are of a form very different from those of the subsequent rows. As they take their origin from a plane surface, two of the sides necessary to complete the hexagon are cut off by this plane, so that the general form of the orifice is pentagonal; and the bottom of the cells on one side is composed of two equal rhombs only, and on the other side of two trapezoidal planes, with one rhomb. Such a modification of shape was necessary, in order to prepare the way for the regularly-formed cells which were to follow.

The foundations of the combs are laid by the bees raising a solid block or plate of wax of a semicircular form. In this they scoop out a small vertical channel, of the size of an ordinary cell. The sides of this channel are then strengthened by additions of wax. On the opposite side two other channels are formed, one on each side of the plane opposite to the former channel. The extremities of these channels, which at first present a curved outline, are then fashioned into straight walls, forming an angle at each vertex. The bottom of each cell being thus sketched out, the design is completed by raising walls round the sides. Different bees generally work on the opposite sides at the same time, and appear to have some perception of the thickness of the partitions, and of the situation of the opposite walls, in which they are perhaps guided by slight prominences, occasioned by the depressions which correspond to them on the other side; and they scrape off the wax in those places where its thickness is greatest, that is, where the bees on the other side had accumulated materials. In this way, then, in constructing the successive rows, the axis of each cell will be found to occupy the most retiring parts of the partition, and will be opposite to the junction of three of the opposite cells.

Soon after the bees have completed the foundations, and constructed a few of the cells of the central comb, they begin two others, one on each side, at the proper distance, and in this manner continue to form others in succession, in proportion as the former are advanced. Their object at first seems to be to extend the surface of the work so as to admit of the greatest possible number of workers being employed at one and the same time. In this way, then, the work proceeds from all points at once, new cells being begun before the former are completed, so that the whole comb; while it is in progress of construction, has a semi-lenticular shape, broader at the top, and tapering below and towards the sides. It extends downwards, however, more rapidly than in any other direction, and its surfaces do not become parallel to each other till the last stage of the building process. When this is completed, the whole is further strengthened by an additional coating of propolis round the margin of all the cells; and the junctions of every plane, both of the sides and bottoms of the cells, are also soldered together by a lining of the same substance. The edges of the combs are also secured in their situations by being glued to the side of the hive and supported by fresh abutments of propolis. Sometimes a mixture of wax and propolis, manufactured by the bees themselves, is employed as the cementing material. The first coating of this compound substance is denominated *Commosis* by Pliny, and described as having a bitter taste; the second, or the *Pissoceros* of the same author, is stated to be of a thinner consistence, and more adhesive than the former, while the third substance, or *Propolis*, is completely solid.

The cells recently constructed are white, but become gradually darker, and, when very ancient, are almost black. It is therefore easy to distinguish in a hive the successive periods of formation of different portions of the combs. From the researches of Huber, it appears that these variations of colour are not owing to any changes in the wax itself, but to additional coatings of a peculiar varnish, consisting of propolis and a colouring matter. The latter differs materially from propolis, being wholly insoluble in alcohol. It loses its colour by the action of nitric acid or the light of the sun. Its origin has not yet been discovered, nor has the mode in which it is applied been clearly made out, although Huber presumes, from his observation, that the bees spread it by means of their mandibles, since he has seen them rub these against the sides of the cells, and noticed that they acquired a yellow colour from the operation.

Royal cells are only formed when it is necessary that queens should be reared, either from their being required to lead off swarms, or from the fact of the colony being queenless through accidental circumstances. Royal cells.

The comb of the hive may be said to be the furniture and storehouse of the bees, which by use must wear out; but, independently of this, it will in time become unfit for use, by the accumulation of cocoons, which are never removed. These line the whole cell, sides, and bottom. Hunter counted above twenty different linings in one cell, and found the cell about one-quarter or one-third filled up. Cell linings.

Lord Brougham made some interesting observations on the cells of bees. By boiling the comb in alcohol after it had been bred in, he succeeded in dissolving the wax, leaving the lining only, which was found to be an extremely thin transparent or semi-transparent film, resembling gold-beaters' skin, without a wrinkle. The linings from old cells with thick walls kept the shape of the cells most distinctly. They had angles and planes as well defined as those of wax in the new comb, but they did not consist of a single film like the cells where one brood only had been raised. They had one film within another, and could be separated, so that as many as five or six could be extricated from the same cell; each of these had the hexagon form, and the first two, and sometimes three, had the rhomboidal form of the base also, but the innermost ones had the rhombuses less and less distinctly marked, till the last one or two of all had spherical instead of pyramidal bases. The film adhered so closely to the wax as to defend it from the action of the solvent and even from that of heat, preventing it from melting for a considerable time. The film fitted the wax cells so completely that there never was found the least wrinkle or laxity, each being tensely

stretched in all its parts without any interval in any part. The whole of each cell was one entire piece of film going all round the prism and all through the pyramid without any breach, section, or joining; neither maceration nor even boiling in turpentine, ether, or caustic potash had any effect on the film.

A film of the same substance, transparent but considerably thicker, was found to line the queen-cells, assuming the pear or flask-like shape of the wax, and a very remarkable fact was observed. The film was not always in the inside; it sometimes lay imbedded in the wax, at least a layer of wax was laid over it of sensible thickness, indeed considerably thicker than some plates of the common cell, and sometimes much thicker. As a queen-cell is never used but once, never more than a single film can be found in it. How this lining is formed has never been satisfactorily determined, but it must be in one of two ways,—either by the larva forming a cocoon round itself and of an oblong figure inside, sufficient to contain it when it changes its position from a coil perpendicular to the axis of the cell into an oblong worm placed in the axis, or by the larva lining the walls of the cell. In the former case the cocoon, originally made somewhat of the shape of the larva, must afterwards be applied by it or by the chrysalis so as to line and adhere to the walls; in the latter case the walls are lined at first by the act of weaving or spinning. But there are difficulties attending both these hypotheses and the inferences to which they lead—inferences in either case as extraordinary, to say the least, as anything observed in the economy of the bee. If the cocoon is formed loose and round, then, when the transformation takes place, the pupa must press against every part of the cell, so as to apply the film all round and equally in every part. The extraordinary part is the perfect adaptation of the cocoon to the cell. There is no wrinkle whatever. It fits exactly in every part, both the planes and the dihedral angles and the trihedral angles. The extreme fineness of the texture may facilitate its fitting so many different shapes. But how is the size sufficient and not more than sufficient in any one place? If we only consider what extreme complexity and difficulty there would be in forming a cocoon—which should increase at every hair's breadth, and increase in a ratio varying at different points, and should, on reaching its maximum size, continue afterwards stationary in dimensions—we shall be convinced how insuperable the difficulties of the workmanship would be to any artist ever so expert or careful. But even this is not all, for as the web is to be afterwards by the supposition applied to the circumscribed walls, the extent of the curved surface of the cocoon inscribed must be less than that of the surface which it is afterwards to line if that curve is wholly concave to the axis, in other words, if it have no points of contrary flexure. In order, therefore, that it may be exactly equal to the walls which it is to fit exactly, the cocoon must be of a form wholly different from that of the larva that made it. It must be convex at some points and concave at others to the larva; it must be loose and baggy, and the progress of its bagging or being loose must vary at every point in order that when applied to the walls it may exactly fit them at every part. The performance of such a work by the larva appears scarcely conceivable. Astonishing as the known and ascertained works of the perfect insect are, this would surpass them in a proportion that might almost be called infinite. If we adopt the second inference, we get rid entirely of the former difficulty; for the operation of forming the film upon the walls is certainly much more easy. With the utmost nicety and precision, there is never a break to be found, and there is no part thicker than the rest, so that but one layer is applied everywhere: and the larva knows so accurately where it has begun as always to leave off on coming round to that point without ever going again over the same ground for half a hair's breadth. The material is also very remarkable. A very high magnifying power shows no threads or separate pieces of any kind; in the great bulk of the texture, it is for the most part solid and perfectly transparent. There are interspersed irregularly a few fibres, but it should seem as if the whole was a mucilage spread over the walls rather than any webs of woven threads. But though the difficulties attending the other theory are not found in this, it has difficulties of a different kind and equally startling. The first that strikes us immediately is the use of the cocoon formed on the waxen walls. The cell was already made, and of the required form and dimensions, in which the larva could be lodged and grow and undergo its transformations. How was the lining it with the film to assist the process? If the cocoon had been of another form and wrapt round the larva, it might have served some such purpose of covering or support; but here the cocoon exactly fits the cell and in nowise alters its form, and only by an exceedingly small portion its capacity. And how are the second and subsequent cocoons to be accounted for? The cell had been already completely lined with the film, and the additional lining could add nothing to the advantage, whatever it was, which the first lining gave the larva and chrysalis. (See Brougham's *Works*, vol. vi. pp. 312-364.)

Different kinds of cells.

Such is the general outline of the architectural labours of the bee. A number of modifications are, however, met with, adapting them to various purposes and to new circumstances. The cells are required to be of different sizes for the nurture of different sorts of larvæ. The smallest, which are also the most numerous, are appropriated to the larvæ of the working bees; a larger sort receive those of the males; and a small number of very large cells are destined for the education of the young queens, and are therefore called royal cells. The first set are generally five and one-third lines in depth, and two and a half in diameter; the second are from seven to seven and a half lines in depth, and three and three-fourths in diameter; while the royal cells are above one inch deep, one-third of an inch wide, and their walls are much thicker than those of any other cells. Other cells, again, are set apart as magazines of honey or of pollen; they are made deeper than the common cells, sometimes as deep as two inches, and their axes are inclined to the horizon, so that their mouths are in the highest part, that their liquid contents may be more easily retained. When these are filled they are closed up by the bees with a wall of wax, and opened only when necessity requires.

The regularity of the cells is often disturbed in consequence of the admixture of rows of larger cells with those of smaller dimensions; but the pyramidal partitions are adapted by successive gradations to these changes, so that in many rows of what may be called cells of transition, the bottom presents four planes instead of three, two being trapeziums, and the other two irregular hexagons. These irregularities are met with chiefly in the combs most distant from the central one. When an abundant supply of honey induces the bees to lay up a large quantity in store, they build up for this purpose the walls of common cells, so as to give them a greater depth. The royal cells are often raised from the ruins of a number of other cells, which are destroyed to make room for them; they are usually built on the edge of some of the shorter combs, and often in the very centre of the hive. Sometimes there is but one; at other times as many as sixteen have been counted in the same hive. They are formed of a mixture of propolis and wax; their form is oblong, resembling that of a pear; their position is always vertical, so that

when they rise from the midst of other cells, they are placed against the mouths of those cells, and project beyond the common surface of the comb. They are perfectly smooth on the inner surface, while their outer side is covered with a kind of hexagonal fret-work, as if intended for the foundation of regular cells.

The impregnation of the queen-bee was formerly involved in the deepest obscurity, and has given rise to a multitude of very fanciful opinions. Some have denied that any intercourse with the male was necessary for the fecundation of the eggs. Swammerdam supposed that the mere effluvia proceeding from the males where they were collected in clusters was sufficiently active to produce this effect by penetrating the body of the female. Huber proved by decisive experiment that no such consequence resulted from these effluvia. Maraldi imagined that the eggs were fecundated by the drones after being deposited in the cells in the same way that the spawn of fishes is rendered prolific by the milt. Mr Debraw of Cambridge gave an account, in a paper published in the *Philosophical Transactions*, of a milk-like fluid he had seen in the cells. But this appearance Huber showed to be a mere optical illusion arising from the reflection of light at the bottom of the cells. When the males are excluded from the hive the queen is as fertile and the eggs as prolific as when they are present. Hattorff supposed that the queen is capable of impregnating herself, an opinion which was supported by Schirach and Wilhelmi, and was even favourably received by Bonnet, as it in some measure accorded with his discoveries respecting the aphis. Linnæus was of opinion that an actual union between the sexes took place, and Reaumur fancied he had seen this happen within the hive. There is, however, great reason to think he was mistaken. It has since been clearly proved that copulation takes place in the air during flight, and if the queen is confined to the hive either by bad weather, or malformation or mutilation of her wings, although she may be surrounded by drones, she never becomes impregnated; and if she does not find a mate within three weeks of her birth, the power of sexual intercourse seems to become lost. If a hive containing a virgin queen be attentively watched on fine days the queen will be observed preparing for her matrimonial flight, and after having attentively surveyed her home so as to be able to recognize it again she flies to a considerable height in the air; and if her errand is successful, in half an hour she returns to the hive with unequivocal proofs of the intercourse that has taken place, for she has in fact robbed the drone of the organs concerned in this operation; and the drone, thus mutilated, is left to perish on the ground. From its being necessary that the queen should fly to a distance in order to be impregnated, Huber infers the necessity of a great number of drones being attached to the hive, that there may be a sufficient chance of her meeting one of them during her aërial excursion.

The phenomenon that sometimes occurred in a bee-hive, of the queen laying eggs that produced males only, had for ages puzzled philosophers without any satisfactory solution, and it was reserved for Dzierzon to promulgate a new and startling theory of reproduction, which, in the words of its distinguished author, is said to have "explained all the phenomena of the bee-hive as perfectly as the Copernican hypothesis the phenomena of the heavens." Dzierzon first expressed his views upon the reproduction of bees in the year 1845. The principal points of this theory may be shortly expressed thus:—1*st*, That the queen (female bee), to become good for anything (*i.e.*, to breed *workers*), must be fertilized by a drone (the male), and that the copulation takes place only in the air; that drone eggs do not require fecundation, but that the co-operation of the drone is absolutely necessary when worker bees are to be produced; that in copulation the ovaries are not fecundated, but the seminal receptacle (or spermatheca), a little vesicle or sac opening into the oviduct, which in the young queen is filled with a limpid fluid, is saturated with semen, after which it is more clearly distinguishable from its white colour; and that the supply of semen received during copulation is sufficient for her whole lifetime. The copulation takes place once for all, and (as already stated) only in the open air; therefore no queen which has been lame in her wings from birth can ever be perfectly fertile, that is, capable of producing both sexes, as copulation never takes place in the interior of the hive. 2*d*, All eggs which come to maturity in the ovaries of a queen-bee are only of one and the same kind, and when they are laid without coming in contact with the male semen, become developed into male bees. This theory of Dzierzon's has since been amply confirmed by numberless experiments, although what power the queen possesses (or how she exercises it) of determining what eggs shall receive fecundation and what not, is yet a mystery. Certain it is that when the queen lays an egg in a drone cell, a drone is produced; and Von Siebold, who made many most skilful microscopical examinations of eggs, affirms that among fifty-two eggs taken from worker cells, examined by him with the greatest care and conscientiousness, thirty-four furnished a positive result, namely, the existence of seminal filaments, in which movements could even be detected in three eggs; and among twenty-seven eggs from drone cells, examined with the same care and by the same method, he did not find one seminal filament in any single egg either externally or internally. On the passage of the eggs from the ovary through the oviduct they pass the opening of the spermatheca, from which some eggs receive a portion of the seminal fluid,—these produce workers; other eggs pass without receiving the fluid,—these produce drones. What it is that governs the deposition or non-deposition of the seminal fluid on the egg is unknown. It has been suggested that the smaller diameter of the worker cells exerts some mechanical pressure on the queen's organs, which may cause the seminal fluid to be extruded as the egg passes, while the drone cells being larger this pressure is not by them exerted, and the egg passes unfecundated. If the spermatheca of an impregnated queen be examined under the microscope its contents will be found to contain many thousands of spermatozoa, the characteristic movements of which are very visible. The contents of the spermatheca of a virgin or drone-breeding queen, similarly examined, will be found a limpid fluid only without a trace of spermatozoa.

The fact that the eggs of an unimpregnated queen will hatch and produce drones may be easily verified, and is now undisputed. By depriving a colony of its queen late in the year, a young queen will be reared; and the drones having been killed long before, no impregnation can take place, yet the queen will infallibly lay eggs which hatch into drones; these eggs are laid indiscriminately in drone and worker cells, the bees bred in the latter being stunted in their growth. If now the spermatheca be examined, no spermatozoa will be found present. The same result will be found if, in the summer, the virgin queen be deprived of her wings and so made unable to fly.

If the impregnation of the queen be delayed beyond, as elsewhere stated, the twenty-first day of her life, she becomes incapable of receiving impregnation, and begins soon after to lay the eggs of drones, and produces no other kind of eggs during her life. This very curious and unexpected fact was discovered by Huber; and has been satisfactorily established by his very numerous and varied experiments, although its explanation is perhaps

attended with insuperable difficulties. The abdomen of a queen that is unimpregnated is much more slender than that of one which is completely fertile; but, on dissection, the ovaries are found expanded and full of ova.

One of the most remarkable facts concerning the generation of bees, is the existence occasionally of prolific workers, the discovery of which we owe to Reims. Although it was doubted by Bonnet, its reality has been fully confirmed by the researches of Huber and subsequent observers, and it explains what was before inexplicable—the production of eggs in hives absolutely destitute of a queen. It is also remarkable that the eggs thus produced are always those of drones, but this is explained by the fact that these fertile workers have not received, and, in fact, are unable to receive, impregnation from the drone. The origin of these abnormal egg-layers is accounted for from their having passed the larva state in cells contiguous to the royal ones, and from their having at an early period devoured some portion of the stimulating jelly which was destined for the nourishment of the royal brood, their ovaries thus receiving a partial development; or when a colony is deprived of its queen late in the autumn, and an attempt to raise a queen from some unknown cause has failed, a larva has sufficiently advanced to develop into a fertile worker.

Deposition of eggs.

As soon as a sufficient number of cells have been constructed, the queen begins to deposit her eggs. Unlike most insects the queen-bee deposits eggs ten or eleven months in the year in temperate climates, although it is probable this is not the case when the winter is much more severe than in Britain. Young queens ordinarily commence ovipositing thirty-six hours after impregnation. What power, if any, the queen has in determining the sex of her eggs is unknown, but, as already noticed, eggs that will produce workers or queens will always be found laid in worker cells, and those that will produce drones will also be found in their appropriate cells. A queen of a new swarm will rarely produce drones the first year; instinct, seemingly, teaching her they will not be required. In the early spring, if a clean empty piece of drone comb be put into the centre of the brood nest, the queen will usually fill it with drone eggs, and this circumstance is taken advantage of by scientific apiarians to secure a supply of drones for the impregnation of early hatched queens. When the eggs are about to hatch, the bees eagerly seek for that species of nourishment on which the larvæ are to be fed. This consists of pollen with a proportion of honey and water, which is partly digested in the stomach of the bees, and made to vary in its quality according to the age of the young. The egg of a bee is of a lengthened oval shape with a slight curvature and of a bluish white colour. It is hatched without requiring any particular attention on the part of the bees, except that a proper temperature be kept up, in which case three days are sufficient for the exclusion of the larva. This has the appearance of a small white worm without feet, which remains generally coiled up at the bottom of the cell. The bees feed it with great assiduity with the kind of chyle above described, and in every respect exhibit towards it the greatest care and attention. Hunter says a young bee might easily be brought up by any person who would be attentive to feed it. As it grows up it casts its cuticle like the larvæ of other insects. In the course of five or six days it has attained its full size, and nearly fills the cell in which it is lodged. It now ceases to eat, and the bees close up its cell with a covering of wax, or rather an admixture of wax and propolis, which they possess the art of amalgamating. During the next thirty-six hours the larva is engaged in spinning its cocoon, and in three days more it assumes the pupa state. It is now perfectly white, and every part of the future bee may be distinguished through its transparent covering. In the course of a week it tears asunder its investing membrane, and makes its way through the outer wall of its prison in its perfect form. Reckoning from the time that the egg is laid, it is only on the twenty-first day of its existence that this last metamorphosis is completed. No sooner has it thus emancipated itself than its guardians assemble round it, caress it with their tongues, and supply it plentifully with food. They clean out the cell which it had been occupying, leaving untouched, however, the greater part of the web, which thus serves to bind together still more firmly the sides of the comb. The colour of the bee when it quits the cell is a light grey. For several days, sometimes a week or two after birth, the worker bees occupy themselves within the hive, not flying abroad during that time, their principal employment then being that of nurses; and many old observers thought them a different class altogether from the honey-gatherers and wax-makers. The metamorphosis of the male bee follows the same course, but requires four days longer for its completion, occupying twenty-five days from the time of the egg being laid to the attainment of the perfect state.

Metamorphosis of the queen.

When from the egg or young larva it is the intention of the bees to raise a queen, their attention is more incessantly bestowed upon it, the cell being enlarged as elsewhere described. It is supplied with a peculiar kind of food, which appears to be more stimulating than that of ordinary bees. It has not the same mawkish taste, and is evidently acid. It is furnished to the royal larva in greater quantities than can be consumed, so that a portion always remains behind in the cell after the transformation. As a proof that any worker egg or young larva not more than three days old may be made to produce a queen, the experimenter has only to supply to such an one a portion of royal jelly, and the nurses will enlarge its cell and continue so to feed it, when in due time a queen will be produced. The growth of the larva and the development of all its organs are very much accelerated by this treatment, so that in five days it is prepared to spin its web, and the bees enclose it by building up a wall at the mouth of its cell. The web is completed in twenty-four hours; two days and a half are spent in a state of inaction, and then the larva transforms itself into a pupa. It remains between four and five days in this state, and thus on the sixteenth day after the egg has been laid, the perfect insect is produced. When this change is about to take place, the bees gnaw away part of the wax covering of the cell till at last it becomes pellucid from its extreme thinness. This not only must facilitate the exit of the bee, but may possibly be useful in permitting the evaporation of the superabundant fluids.

Rivalship of the queen.

But the queen bee, although perfectly formed, is not always at liberty to come out of her prison, for if the queen-mother be still in the hive waiting a favourable state of the weather to lead forth another swarm, the bees do not suffer the young queens to stir out; they even strengthen the covering of the cell by an additional coating of wax, perforating it with a small hole through which the prisoner can thrust out her tongue in order to be fed by those who guard her. The royal prisoners continually utter a kind of plaintive cry, called by bee-keepers "piping," and this appears to be answered by the mother queen. The modulations of this piping are said to vary. The motive of this proceeding on the part of the bees who guard them is to be found in the implacable hatred which the old queen bears against all those of her own sex, and which impels her to destroy without mercy all the young queens that come within her reach. The workers are on this account very solicitous to prevent her even approaching the royal cells while there is any prospect of a swarm being about

to issue. They establish themselves as a guard around these cells; and, forgetting their allegiance on this occasion, actually beat her off as often as she endeavours to come near them. If, on the other hand, the swarming season is over, or circumstances prevent any further swarms from being sent off, the bees do not interpose any obstacle to the fury of the old queen, which immediately begins the work of destruction, transfixing with her sting one after the other the whole of the royal brood, while they are yet confined in their cells. It is observed by Huber, that the royal larvæ construct only imperfect cocoons, open behind, and enveloping only the head, thorax, and first ring of the abdomen; and he conceives that the intention of Nature in this apparent imperfection is, that they may be exposed to the mortal sting of the queen, to whom they may be given up as a sacrifice.

When the old queen has taken her departure along with the first swarm, the young queens are liberated in succession, at intervals of a few days, in order to prevent their attacking and destroying one another, which would be the infallible consequence of their meeting. This exterminating warfare is prevented by the vigilance of the bees which guard them, so long as new swarms are expected to go off. When a young queen is liberated, she is, like others of her sex, anxious to get rid of her rivals, and even at that early age seeks to destroy her sisters, which are still confined in the other royal cells; but as often as she approaches them she is bit, pulled, and chased without ceremony by the sentinels. But when the season is too far advanced for swarming, or if two or more queens should happen to emerge at the same moment, they mutually seek each other and fight till one is killed, and the survivor is immediately received as the sovereign of the hive. The bees, far from seeking to prevent these battles, appear to excite the combatants against each other, surrounding and bringing them back to the charge when they are disposed to recede from each other, and when either of the queens shows a disposition to approach her antagonist, all the bees forming the cluster instantly give way to allow her full liberty for the attack. The first use which the conquering queen makes of her victory is to secure herself against fresh dangers by destroying all her future rivals in the royal cells; while the other bees, which are spectators of the carnage, share in the spoil, greedily devouring any food which may be found at the bottom of the cells, and even sucking the fluid from the abdomen of the pupæ before they toss out the carcasses.

Swarming.

We are now to direct our attention to the migrations of bees, by which new colonies similar to that which had originally peopled the parent hive are founded. The final causes of this phenomenon are sufficiently obvious, but it does not so clearly appear to what circumstances it is immediately owing. The increasing population of a hive probably occasions inconvenience from want of room; the increase of heat and the greater vitiation of the air become still more serious as the summer advances. The spring is, accordingly, the commencement of the swarming season. No swarming, indeed, will ever take place while the weather is cold, or until the hive is well stocked with eggs. The queen-bee, in consequence of the great number of eggs she has been laying, is now reduced to a more slender shape, and is well fitted for flight; her aversion for the royal brood, which she seems to foresee will in a short time become able to dispute the throne with her, and the vain attempts she makes to destroy them in the cradle, in which attempts she is invariably repelled by the bees who guard them, produce in her a constant restlessness and agitation which, as Huber represents it, rises to a degree of delirium. This frenzy, from whatever cause it may originate, is communicated to the workers; they may be seen hurrying to and fro in the combs with evident marks of impatience. The heat of the hive is increased by their tumultuous movements; it sometimes rises suddenly on these occasions from 92° to above 104°. A general buzz is heard throughout the hive. This state of things occurs from time to time for some days before the swarm is actually on the wing; and the interval is occupied in making preparations for the approaching expedition; provisions are collected in greater quantity by the workers. Hunter killed several of those that came away, and found their crops full, while those that remained in the hive had their crops not nearly so.

On the day on which the swarm quits the hive, few of the workers roam to any distance, but several are seen performing circles in the air round the hive. The noise is on a sudden hushed, and all the bees enter the hive; this silence announces their immediate departure. A few workers appear at the door, turn towards the hive, and striking with their wings, give, as it were, the signal for flight. All those which are to accompany the expedition rush towards the door, and issue forth with wonderful rapidity, rising in the air and hovering for some time, as if in order to wait for the assemblage of the whole troop; then, having selected a rallying point, generally on some tree or bush, some alight, being joined immediately by others until the whole number is collected in one mass of bees. It does not always happen that the queen is the first to alight or is with the cluster at all; but if she be not there the bees soon discover it and disperse in search of her—if they fail to find her they return to the parent hive. Thither the queen sometimes, from weakness or other causes, returns, and is immediately attended by the rest. But if the weather be fine, the expedition is only deferred for one or two days, and they again take their departure. If their return be owing to the loss of their queen, they remain a fortnight or longer before the attempt to migrate is renewed, and then the swarm is much larger than before, which renders it probable that they have waited for the queen that was to go off with the next swarm. Sometimes, when everything indicates an approaching emigration, the passage of a cloud across the sun will suspend all their operations, and the previous bustle gives place to a state of perfect calm. But, if the day be not far advanced, the breaking out of sunshine will renew the commotion, and determine the moment of actual flight.

The swarm having rested for some time on the first landing-place, and collected the whole of its numbers, soars again in the air, keeping in a close phalanx, and directing its course with great velocity to the spot which their guides had selected,—giving out, at the same time, a loud and acute-toned hum by the action of their wings.

The parent hive, thus deserted by its queen and a large proportion of its inhabitants, is busily occupied in repairing its loss. The bees which remain quietly pursue their labours; the young brood, soon arriving at maturity, quickly fill up every deficiency; and young queens, being allowed their liberty, one after the other, conduct in their turns new swarms, in the same manner as the first. The second swarm is not sent off till after the space of from five to ten days after the first. The following swarms succeed quicker to each other, but consist of smaller numbers than the earlier ones. If it happen that two queens are found in a swarm, either the swarm divides itself into two, and have separate destinations, or a single combat between the queens decides on which of them the empire is to devolve. Sometimes, indeed, they appear not to perceive each other, and the parties belonging to each construct separate combs within the same hive; but no sooner do these combs come in contact, and thus give occasion to the queens meeting each other, than a contest begins which terminates only by the death of one of the rival queens.