manure. This substance seems to be its favorite larval food.

At Salem, Mass., Packard states that he bred a generation in fourteen days in horse manure. The duration of the egg was twenty-four hours, the larval state from five to seven days, and the pupal state from five to seven days. At Washington Mr. Howard found in midsummer that each female lays about 120 eggs, which hatch in eight hours, the larva period lasting five days and the pupa five days, making the total time for the development of the generation ten days. This was at the end of June. The periods of development vary with the climate and with the season, and the insect hibernates in the puparium condition in manure or at the surface of the ground under a manure heap. It also hibernates in houses as adult, hiding in crevices.

The Washington observations indicate that the larvæ molt twice, and that there are thus three distinct larval stages.

The periods of development were found to be about as follows: Egg from deposition to hatching, one-third of a day; hatching of larva to first molt, one day; first to second molt, one day; second molt to pupation, three days; pupation to issuing of the adult, five days; total life round, approximately ten days. There is thus abundance of time for the development of twelve or thirteen generations in the climate of Washington every summer.

The number of eggs laid by an individual fly is undoubtedly large, averaging about 120, and the enormous numbers in which the insects occur is thus plainly accounted for, especially when we consider the abundance and universal occurrence of appropriate larval food. In order to ascertain the numbers in which house-fly larvæ occur in horse-manure piles, a quarter of a pound of rather well-infested horse manure was taken on August 9, and in it were counted 160 larvæ and 146 puparia. This would make about 1,200 house flies to the pound of manure. This, however, cannot be taken as an average, since no larvæ are found in perhaps the greater part of ordinary horse-manure piles. Neither, however, does it show the limit of what can be found, since about 200 puparia were found in less than 1 cubic inch of manure taken from a spot 2 inches below the surface of the pile where the larvæ had congregated in immense numbers. —Abstracted from a Bulletin issued by the Dept. of Agriculture.

SOME RUDIMENTARY STRUCTURES.*

By R. LYDEKKER.

ON a first visit to an English assize court, the stranger, if he occupy a sufficiently elevated position, will scarcely fail to notice the presence of a small black patch on the top of the full-bottomed wig of the presiding judge, and, if he be of an inquiring disposition, he will want to know the reason for this apparently useless feature. Reference to any treatise on the history of costume will inform him that this apparently unmeaning patch is the last remnant or survival of the coif, or black cap, with pendent lappets, originally worn by the "sergeants learned in the law," from among which body the judges were formerly selected. The patch affords therefore an excellent example of a structure which, although now perfectly useless, once had a definite and more or less important function. In other words, it exactly corresponds to what are commonly called rudimentary structures in the animal kingdom. I say commonly called rudimentary structures, purposely, because in scientific circles they are now more generally designated vestigiary structures; and, strictly speaking, quite rightly so, for a rudiment properly means the commencement of anything, whereas these are the last vestiges of the structures they represent. They are decadent, and not in-

FIG. 1.—THE LEFT FORE AND HIND LIMBS OF A HORSE, TO SHOW THE CALLOSITIES, OR "CHESTNUTS."

cipient. Nevertheless, since the term vestigiary is somewhat cumbrous, and by no means so well known as rudimentary, I shall take leave to use the latter, especially as it is employed by Darwin, in this sense, in the "Origin of Species."

Rudimentary, or more or less completely functionless organs are extremely common in both the animal and the vegetable kingdoms; and they can have but one meaning. That is to say, they afford practically decisive and irrefutable evidence in the minds of all unprejudiced persons of the truth of the doctrine of evolution. For it is absolutely inconceivable that such useless structures, which in many instances can be traced by regular gradations into those which were evidently functional, could have been created in their present condition. Indeed, if we had no other evidence in favor of the evolution of animal forms from pre-existing types, it is perhaps not too much to say that the evidence of these rudimentary structures

FIG. 2.—PART OF THE SKIN OF THE TAIL OF A PYTHON, SHOWING THE HORNY SPURS REPRESENTING THE HIND LIMBS.

would alone be sufficient to prove the truth of that great doctrine.

Since rudimentary structures are so common in nature we suffer from an *embarras de richesses* in attempting to select instances to form the subject of a short article; and the reader must consequently be not surprised if he finds no mention of many cases of this kind with which he may be more or less familiar. As a matter of fact, cases of this nature to which the present writer has had occasion to devote special attention form the chief of those noticed in this article.

Among the larger animals of the present day, no species is more highly specialized than the horse (and its immediate relatives), and it would consequently be only reasonable to expect that in the course of its evolutionary progress this creature should have found certain elements in its organization superfluous, and

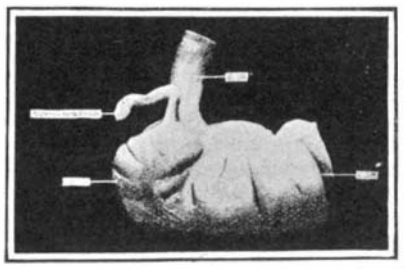

FIG. 3.—THE VERMIFORM APPENDIX, AND THE ADJACENT PARTS OF THE HUMAN ALIMENTARY CANAL.

should therefore have done its best to discard them. This expectation is fully realized by the actual state of the case; and it may be regarded as a fortunate circumstance that the total elimination of such superfluous structures appears to be an exceedingly difficult process, so that their rudiments, or vestiges, are frequently left to tell the tale of their gradual degeneration.

As regards some of the rudimentary organs occurring in the horse, one of the most interesting is the remnant in the skull of the eastern breeds, of the cavity in front of the eye, which in the extinct three-toed hipparions probably contained a gland similar to the larmier, or face-gland, of deer and many antelopes.

At first sight there may seem to be little, if any, connection between this last vestige of the hipparion's face-gland, and those curious warty structures on the inner side of the limbs of the horse, which are commonly known as callosities, or chestnuts (Fig. 1). It appears to be a very general belief that these structures are for the purpose of serving as cushions, or pads, to ease the pressure on the limbs when the animal is lying down. This, however, is obviously out of the question; and it is quite certain that the callosities are now useless remnants of structures that were once functional. The question is what those structures were. One theory is that they were foot-pads, or cushions, comparable to those on the foot of a dog or a cat; and in order to support this hypothesis, it has been stated that they are situated much lower down on the fœtus than in the adult, so as to be situated on what corresponds to the foot of other mammals. This, however, is not the case.

A much more probable theory is that these callosities represent scent-glands, comparable to those on the limbs of deer. Strong support to this is afforded by the fact (as I am informed) that the secretion which exudes from these callosities when cut will cause a horse to follow any substance anointed therewith; and also by the poacher's practice of carrying a fragment of one of them to keep his dog quiet. That a rudimentary foot-pad would have any effect of this kind is, of course, quite out of the question, although nothing is more likely than that such emanations should proceed from a decadent foot-gland.

In regard to the connection between the rudimentary face-gland of certain horses, and the callosities, it may be noted that both face-glands and foot-glands appear to be for the purpose of aiding animals in finding the whereabouts of their fellows; the leg or foot glands leaving a scent on the grass or jungle through which they pass. If, however, animals live on open plains, as is the case with horses and zebras, where they can see one another at long distances, such aids may be quite unnecessary. We know that the horse and its kindred have lost the facial scent-glands of their ancestors, and what is more likely than that they should at the same time have discarded their leg-glands, of which the callosities are the last remnants?

That the horse does retain vestiges of the foot-pads of its ancestors, who applied a portion of the sole of their foot, instead of only the nail (hoof) of the middle toe, to the ground, appears, however, to be undoubted. At the hinder basal extremity of the second joint of the pastern is a curious little horny spur (very conspicuous in the fœtus), known to veterinarians as the ergot; and this ergot seems to represent the central pad of the foot of the tapir. As this part of the foot of the horse does not touch the ground, the pad is of no functional importance, and has consequently degenerated to this curious little horny spur.

Other rudimentary organs in the horse are the splint-bones lying on either side of the upper end of the fore and hind canon-bones, and representing the functional metacarpal and metatarsal bones, and sometimes even the lateral toes of the hipparion. In domesticated horses not only are these bones useless, but they are actually harmful, producing the disease called splint. Even this does not exhaust the list of rudimentary structures in the horse. In the "knee," or carpus, of the hipparion exists a bone known as the trapezium, which supports one of the aforesaid metacarpal bones of the lateral toes. In the horse this bone is functionless and very minute, and is present only in about fifty out of every hundred individuals; so that it is evidently about to follow in the wake of the lost lateral toes.

In the horse only certain elements of the limbs have become rudimentary, in order to permit the greater development of other elements of this part of the skeleton. In some groups of animals, on the other hand, one or both pairs of limbs are, in many instances at any rate, completely wanting; and had it not been that they are occasionally represented by minute vestiges, we should have had no direct evidence that they ever existed in the group. As it is, we are absolutely certain (if evolution be the true explanation of the resemblance of animals to one another) that snakes and whales are descended from creatures with four limbs.

In regard to snakes, most members of the group show no traces of limbs, either externally or internally; but in the family groups which include the boa-constrictors and pythons (the *Boidæ* of naturalists) it fortunately happens that in many species, at any rate, minute vestiges of the hind-limbs are retained, as if for the very purpose of telling us the story of their ancestry, for it is quite certain that in most instances, at all events, these rudiments are absolutely useless. The second illustration to this article shows the external vestiges of the hind-limbs in an African python (*Python sebæ*) over twenty feet in length. These vestiges take the form of a pair of horny spurs, or claws, about three-quarters of an inch in length, and situated on the under surface of the body at the commencement of the tail. In the specimen figured, the skin has been slit along the middle line of the belly, so that the two claws are separated from one another by the width of the skin of the back and flanks, whereas in nature they would be comparatively close together. Each claw in this specimen was supported on a bony core, corresponding to the terminal bone of one of the toes of a lizard's foot, while embedded in the flesh beneath was a much stouter bone, probably representing the femur, or thigh-bone, and also a mi-

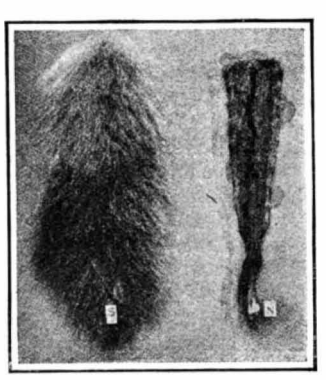

FIG. 4.—TIP OF TAIL OF LION (ON THE LEFT), AND OF NAIL-TAILED WALLABY (ON THE RIGHT), SHOWING HORNY SPUR AND NAIL.

nute nodule, which may be the last remnant of the pelvis. It must not, however, be supposed that all pythons exhibit these vestiges as distinctly as in this specimen. On the contrary, in the skin of a Malay python (*P. molurus*) of five-and-twenty feet in length, which I recently examined, the external rudiments of the limbs were minute lobes, scarcely larger than the head of a big pin. Somewhat similar vestiges of the hind-limbs are retained in the small burrowing tropical snakes of the family *Typhlopidæ*, as well as in the members of a nearly allied group; but in no snakes have any traces of the front-limbs been detected.

* Knowledge and Scientific News.

These vestiges, then, afford decisive evidence that snakes are descended from reptiles with functional hind-limbs, from which it may also be inferred that their early ancestors were four-limbed; the front limbs, as in the case of certain snake-like lizards, being the first to disappear. The further inference that those snakes which retain rudimentary hind-limbs are the most archaic members of their kind, has been recently confirmed by the discovery that pythons and boa-constrictors display certain primitive features in other parts of their anatomy.

Space admits of but very brief allusion to the case of whales. As everyone knows, all the members of the order Cetacea, inclusive of whales, dolphins, porpoises, etc., have but a single pair of limbs, the front ones, which are modified into paddles for swimming. It is, however, far less well known that deep down among the muscles of the body of the Greenland right-whale and its immediate relatives are imbedded certain small and useless bones which represent those of the pelvis, and part of the hind-limbs of less specialized mammals. These rudimentary bones are alone sufficient to demonstrate the descent of whales and dolphins from four-limbed ancestors; and when taken in connection with the fact that cetaceans are air-breathing (as opposed to gill-breathing) creatures, they lead to the conclusion that their ultimate ancestors were terrestrial. Curiously enough, it is the most specialized whales (that is to say, the true, or whale-bone whales) that alone retain rudiments of the hind-limb itself; these vestiges in the toothed whales, such as the sperm-whale and dolphins, being restricted to the bones of the pelvis. In this respect, then, cetaceans are unlike snakes, in which, as we have seen, it is the most primitive forms that alone retain vestiges of limbs.

Turning to the subject of the third illustration, we have an exceedingly interesting example of a more or less completely rudimentary structure, in the so-called worm-like appendage, or *appendix vermiformis*, of the human blind gut, or *cæcum*. In this connection it may be well to mention incidentally, that the disease to which this organ is so frequently subject, derives its name of *appendicitis* from the organ itself, and its alternative title of *typhlitis*, from Greek τυφλος, blind, in reference to the blind gut of which the appendix forms the termination.

In a great number of mammals, both herbivorous and carnivorous, there exists at the angle formed by the junction of the small intestine or ileum with the large intestine or colon, a large blind pouch or diverticulum, which probably aids in the digestion of food by preventing its too rapid discharge. The cæcum, as it is called, is remarkably well developed in the horse and the dog, in the latter of which it is coiled in a spiral manner. In the human subject, on the other hand, the cæcum proper is very short, but is prolonged by the aforesaid vermiform appendage, which is usually from four to five inches in length, with a caliber of only about one-third of an inch. This appendage corresponds to the coiled cæcum of the dog, of which it is obviously an aborted rudiment. As many of us know by sad experience, it is only too likely to become choked by closely packed, partially digested, or undigested food; and the opinion has been very generally held that it is an altogether superfluous and useless organ whose complete elimination would be an unmixed advantage to the human race. For instance, on page 282 of "The Student's Darwin," by Dr. Aveling, we find the following statement in reference to the vermiform appendage:

"It is to man useless. Nay, it is worse than useless. It is at times a special death-dealer. Small, hard bodies, as the seeds of fruits, entering the appendix, cause inflammation and death. In the animals lower than man, this organ is of great size and functional importance. That of the orang-utan is long and convoluted."

On the other hand, an eminent surgeon has recently expressed the opinion that the appendix may still have a certain amount of digestive function. To controvert such an opinion would obviously be presumption on my part; but whether or no it still retains any active function, the structure in question is evidently a pronounced example of a rudimentary organ, and one which, by the way, leads to the conclusion that man is descended from an animal furnished with a long and complex cæcum. Incidentally, it may be mentioned that, in addition to man, the only animal possessing a vermiform appendix is the Australian wombat, a member of the marsupial order. Truly a remarkable instance of parallelism in retrograde development!

With Fig. 4, I come to the last section of my subject, and I must confess that I am by no means certain that it properly belongs to my subject at all. The object represented on the left side of the photograph in question is the tip of the tail of a lion, showing the presence of a small horny prickle or spur (*s*) buried among the terminal tuft of hair. In the natural condition, it should be mentioned, the spur was completely concealed by the long hair, and it was only by cutting away a portion of the latter that it was made visible. What may be the history or use (if it has a use) of this spur, no one seems to know, and I have no intention of hazarding a guess. The old story, that it was for the purpose of enabling the lion to goad itself into a fury when about to attack, is obviously an absurdity, more especially as it seems that the spur is developed in only a comparatively small percentage of lions. If any of my readers can solve this problem, they will be the means of removing one blank from future zoological text-books. I fear it will not help them much to learn that one species of kangaroo, or rather wallaby, possesses a very similar caudal appendage, which is, however, of a somewhat more nail-like form, as shown at *N*, on the right side of Fig. 4.

THE COLORS OF THE SKY AND THE SOLAR DISK.

By PROF. G. SAGNAC.

1. THE Modern Theory of the Blue Color of the Sky.—Science, after many wanderings, has returned to the explanation which Leonardo da Vinci suggested when he compared the color of a cloudless sky to that of smoke seen against a dark background.

The atmosphere, which, according to Arrhenius, extends to a height of 125 miles above the sea level,

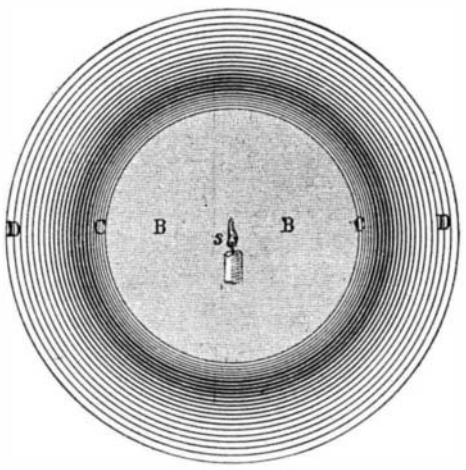

FIG. 1.—SOURCE OF LIGHT VIEWED THROUGH A MIST.

C D, colored rings. B B, central blue field.

breaks up the rays of the sun, scatters them in all directions, and thus becomes luminous and visible. Its color is the result of selective diffusion. In other words, the atmosphere diffuses most powerfully the rays of shortest wave length, diffusing blue more strongly than green, and violet more strongly than blue. The wave lengths whose absence from sunlight produces the dark Fraunhofer lines of the solar spectrum are also absent from the light diffused by the sky, the spectrum of which shows the Fraunhofer lines unchanged in position.

2. Artificial Production of the Blue Color of the Sky. The Blue Center of Diffraction Rings.—When a pane of glass is breathed on the moisture of the breath condenses on the glass in the form of fine dew. A source of light seen through the glass thus coated appears surrounded by colored rings (Fig. 1). If the drops of water which compose the coating are fine enough and the source of light is sufficiently small or distant, the area within the innermost ring has a uniform blue tint resembling the color of a cloudless sky.

These effects are due to a diffusion or diffraction of the incident light by the drops of water. Similar effects are produced by fine powders like lycopodium. The phenomena are not affected by the physical state of the diffracting particles, but only by their size. The smaller they are, the larger the colored rings become, until, when the diameter of the particles is reduced to less than a micron (1/1000 millimeter, or 1/25000 inch) the rings disappear by expansion and the central blue fills the whole field of vision. In other words, every illuminated collection of particles less than 1/25000 of an inch in diameter radiates blue light, like that of the sky, in all directions.

3. Blue Clouds Produced by Precipitation.—These particles, instead of being spread over a pane of glass, may be distributed throughout a volume. In this case we have a blue diffusion cloud—that is, a cloud which appears sky-blue when it is illuminated by white light and seen against a dark background. Such a cloud produces the faint opalescence which precedes the precipitation of solid particles from a liquid or a gas. Tyndall* made some very beautiful experiments on the formation of such blue clouds in air, but similar effects are more easily obtained with liquids. If one part by weight of gum mastic is dissolved in ten parts of strong alcohol and the solution is added, drop by drop and with constant stirring, to a glass of distilled water, the mastic is separated, but remains in suspension, in particles so fine that the water appears blue when seen by daylight against a dark background. If the glass vessel is rectangular and is placed in the path of a sunbeam or a beam projected by an electric lantern (Fig. 2), the beam appears in the liquid as a blue cylinder or cone, *A. B. C. D.* As the mastic settles very slowly the phenomenon can be observed at leisure.

* "Heat as a Mode of Motion," also Proc. R. S, 1868.

Lippmann has obtained a very intense and permanent blue with silver bromide suspended in solidified gelatine, albumen, or collodion. For example, gelatine is dissolved in hot water and a little albumen is added to precipitate impurities. Then a solution of potassium bromide is added and the mixture is allowed to cool. A concentrated solution of silver nitrate is poured on the solidified gelatine, into which it penetrates to the depth of a millimeter (1-25 inch) in a few minutes, forming in the potassium bromide fine particles of silver bromide which produce a blue coloration on a dark background. The gelatine greatly retards the agglomeration of the particles which long remain of "Tyndallian" fineness.

Plates prepared by a similar process for photographing in colors by Lippmann's interferential method also contain particles of gelatino-bromide of silver of extreme fineness,

4. Artificial Sunset.—If, in the experiment illustrated by Fig. 2, the image of a circular aperture placed before the lantern is projected on a white screen by means of the beam which traverses the liquid, this image will appear yellow or orange, the depth of its tint varying with the thickness of the vessel of liquid and the quantity of mastic in suspension. Similarly, a disk of white paper appears yellow or orange when it is viewed through the liquid.

The earth's atmosphere produces an effect of the same character upon the disk of the sun, to which it gives a yellow tinge by subtracting the rays of short wave length from its beams and diffusing them in all directions to produce, as we have seen, the blue color of the sky. As the observer rises through the atmosphere this effect diminishes and the sun's beams become richer in blue, violet, and especially ultra-violet radiations. Conversely, as the sun approaches the horizon its beams traverse a layer of atmosphere of steadily increasing thickness and its disk passes from pale yellow to deep yellow, orange, and finally red. A succession of tints similar to those of the setting sun is easily obtained by replacing the mastic emulsion of the above experiment with a solution of 1 part by weight of sodium hyposulphite in 100 parts of distilled water and adding a few drops of dilute sulphuric or hydrochloric acid. In a few minutes an opalescent blue precipitate of sulphur begins to form, the color of which gradually increases in intensity at first, but finally turns to white in consequence of the increase and coalescence of the particles of sulphur. If these changes occur too rapidly they may be retarded by the prompt addition of a drop or two of ammonia.

While these changes are occurring the light transmitted by the liquid passes from white to yellow, orange, and red, and the image on the screen assumes successively the various complex tints of the setting sun. (A disk of white paper, viewed through the liquid, undergoes similar changes in color.)

If the vessel is not disturbed the sulphur accumulates, especially near the bottom, where it plays the part of the fog-laden lower strata of the atmosphere. The image on the screen (or white disk seen through the liquid) then appears like the solar disk slowly sinking into the mists of the horizon and showing at once every tint from yellow to dark red.

5. Nature of the Particles that Give Rise to the Blue Color of the Sky.—The finely divided matter which disturbs the optical homogeneity of the atmosphere may consist, in part, of solid dust.* The eruption of Krakatoa, in 1883, projected large quantities of ashes to a great height above the earth. The finest particles evidently remained suspended for years at a height exceeding a mile, for even from elevated viewpoints the sun appeared, for several years after the eruption, surrounded by colored rings, which inclosed a central field of an intense blue color. Similar phenomena followed the eruptions of Mt. Pelée in 1902 and 1903. But all such dust falls in time and volcanic ashes, ice crystals, and other foreign matter can hardly be the principal cause of the blue color of the sky. We are led, therefore, to consider the diffusive action of the molecules of the air itself. According to the writer's personal view, the diffusive effect of a given mass of finely divided matter should be proportional to the mean distance between its particles, divided by the wave length of the light diffused.

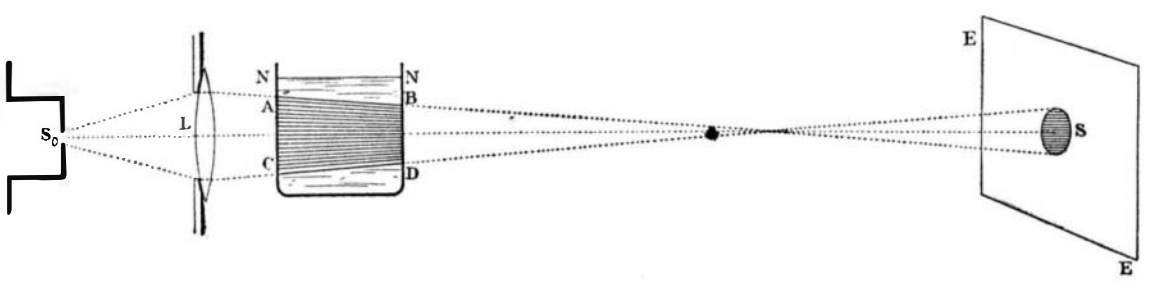

FIG. 2.—ARTIFICIAL SUNSET.

S_0, circular aperture before lantern. S, its image projected by the lens L. N, glass vessel containing diffusing liquid. A B C D, blue trace of beam of light in the liquid

Every substance, even the purest and most homogeneous, must diffuse light in virtue of its molecular discontinuity. In gases at atmospheric pressure the mean distance between molecules is about ten times as great as it is in solids and liquids and the optical diffusion must be correspondingly increased. At the sea level the mean distance between the molecules of the atmosphere is about 0.01 of the wave length of green light. As the wave length diminishes, the diffusion must increase from the red to the violet end of

* See "Les Métaux dans l'Atmosphere," by A. Ditte, Revue Scientifique, Dec. 3, 1904.