Borrowed Plumes

By H. Munro Fox

Secrets from Nature's Beauty Parlor

THE colors of animals are many and varied, and the coloring matters which give these numerous hues are themselves manifold. In the last fifteen or twenty years great advances have been made in our knowledge of animal coloring matters, and scientists now find it possible to classify them into a few simple groups. This can be done from two different points of view, — by the chemical nature of the dye stuffs themselves or by the way in which they are formed in the animal. It is a subject of intense interest.

Although it is not very generally known, one of the biggest groups of animal coloring matters has its origin in breakdown products. The ceaseless chemical processes going on inside of the body produce by-products, some of them colored, others not. Many of these by-products are thrown out by the body. But others may be stored up in the skin, and when these are colored bodies they contribute to the general hue of the animal. All animal black seems to be of this nature. Melanin, as the biologist calls the black substance, is formed by the breakdown of the living stuff, protoplasm. This latter is formed in large part, as everyone knows, of complex chemical substances called proteins. The complex protein molecules are all the time constantly being broken down, and one of their breakdown products is the black melanin. It is seen in human skin and hair, in black birds and fishes, in the cuttlefish's sepia ink, and in innumerable black worms and slugs. Melanin is merely a black waste from the point of view of the living animal's chemical exchange, but the melanin may be used for defensive purposes in a black skin or in the ink which the cuttlefish shoots out when danger threatens, just as a destroyer lays a smoke cloud around a battleship.

The black stuffs, then, come from the breakdown of proteins. But there is more than this. The microscopic cells which compose the living body have each of them a minute central body called a nucleus. Now, the proteins of the nuclei have their own colored breakdown products, but in this case they are not black. Uric acid is one of them. While most animals throw out their uric acid, some few make use of it for skin coloration. Such is the case with certain butterflies. The so called Cabbage White has yellowish patches on its wings, which are colored by uric acid, and the white, shining stuff called guanin which gives the shimmer to fishes is another result of the breakdown of the cell nuclei.

One last example of a most brilliant color due to breakdown, is indigo, which is formed from one part of the complex protein molecule. Most indigo is formed by plants, but not all, for the imperial purple is the same stuff, and, as I have already pointed out in a previous article, it was procured in Roman days from a sea snail which produced the purple as a waste product of its life activities.

Blue Blood in the Lower Classes

Another very important group of these pigments is that to which the red coloring matter of blood, hemoglobin, belongs. All chemical stuffs falling in this family of pigments have a complicated but very definite structure. Four chemical groups called pyrrols are joined together in the molecule by a metal. In the case of hemoglobin, this metal is iron. In the case of chlorophyl, the green coloring matter of plants, the metal is magnesium. Some animals, too, have another green stuff of very much the same sort, which contains iron and is found in the blood. For, strange though it may seem, there are creatures with green instead of red blood. These are certain worms living in the sea, and others again among the lower classes of animals, — crabs and the octopus, for example, — have blue blood, like the pure-bred Spaniard of fiction. The blue substance contains the metal copper. This is strange enough, for the shell-fish must obtain their copper from the sea water. Yet so little copper is present in the sea that chemical analysis can not detect it at all.

But pass on. For, leaving the colored breakdown products and the blood pigments with their metals, I propose to go on to a third big group of animal colors. These are red and yellow stuffs which have since half-way through last century been called lipochromes, — or, in other words, fatty colors. It is only quite lately that the real chemical nature of these colors has been discovered, and now that we know the facts, — as often happens, — they turn out to be remarkably simple. All that was known formerly about the yellow and red lipochromes was that they could be dissolved in those liquids which can also dissolve fats. Such bodies are ether, chloroform, and the like. Moreover their color is very sensitive to light and bleaches rapidly. This may happen even inside the bodies of animals, — goldfish, for example, grow paler in bright light.

These lipochrome colors are found far and wide in animals. They form the yellow of fat and of feathers, and the same pigments are found in frogs and in fishes. The pink flesh of the salmon, for instance, is tinted thus, while the lipochromes also give the red and yellow hues to many beetles, shells, starfish, and sponges.

Carrots and Yellow Flowers

Now modern research has unveiled the surprizingly simple fact that these so called lipochromes are one and the same stuff as the coloring matter of the red carrot, which is colored by a substance known to the chemist as carotin. It has an extremely simple make-up, for it contains carbon and hydrogen alone in its molecules, and it is not confined to the carrot in the plant world. Indeed, it constitutes the coloring matter of most yellow and orange flowers and fruits. The tomato, for instance, the red pepper, and the watermelon are colored thus, and even the green parts of plants contain carotin in fairly large quantities. It is true that the carotin here is masked by the green stuff, chlorophyl. But at harvest time, when crops ripen and the chlorophyl disappears, the yellow carotin is evident enough; and when plants are grown in darkness, — as for instance, grass in the garden under a board or beneath the garden roller, — these plants are yellow. The darkness prevents the green chlorophyl from being formed, and so the carotin is seen. It will be clear shortly how important is this presence of carotin in green leaves, when we come to consider whence animals get their yellow pigment.

Before, however, going on to the question of the origin of so called lipochromes in animals, we must touch on the colors of lobsters and crabs. It is a most amazing fact that not until two years ago did we discover why a lobster turns red when cooked, although this striking color change has been observed by generations of cooks and zoologists. Here again, now that the facts are known, they are surprizingly simple. Yet patient and careful research was required to clear them up.

Why the Lobster Turns Red when Cooked

Some crustaceans, like the lobster, are blue, while others, as many crawfish and crabs, are red. A green color, too, is found, for instance in the eggs of lobsters and in the shells of shore crabs. All these coloring matters, blue, red, and green, have this in common that they can be dissolved in water. When a piece of the animal's skin is rubbed up in a mortar with water, the pigment goes into solution in the water. It is clear at once that these colors are different from those we have called lipochromes, which could be brought into solution only in ether, chloroform, and so forth. When a watery solution of the blue, green, or red dye of our shell-fish is heated, it sets into a jelly or clot. And this clot is always red, no matter what color we started with. An immediate reddening is of course what happens when a lobster is cooked, and the blue in the lobster's skin and shell turns to red. If the clot in our experiment is shaken with ether or with chloroform, the red stuff passes over into the latter, the ether or chloroform takes on a red tint, while the clot becomes colorless. The next step in the research was to analyze chemically the red stuff in the ether. When this was carried out, the surprizing fact emerged that the red substance was nothing more or less than carotin. In animals, as we shall see, carotin may come straight from the plant food. The animal tissues are dyed with a plant waste product. In other instances, the animal apparently manufactures its own carotin, as we see to be the case with crustaceans. Here the carotin must be considered as a natural excretion or breakdown product, just as are melanin, guanin, and uric acid. Color as camouflage is necessary for both plants and animals.

So the carrot's color body which gives the yellow tint to so many flowers, fruits, and animals, is present also in the lobster and crab, but not as simple carotin, for not only may it be blue or green or red, but it is soluble in water. To what, then, is the simple carotin tacked on, so to speak, to give it these altered properties? The facts were discovered by analyzing the clot just spoken of. After the red carotin had been removed with ether, the colorless clot was analyzed and found to be composed of a protein. From this it was abundantly clear that in the lobster or the crab carotin is united to a protein. This complex stuff, carotin plus protein, is soluble in water and it may be colored red, green, or blue. When the lobster is boiled, then, the junction of carotin to protein is broken by the heat, and the red carotin emerges.

Nature's Mistakes

One final question will be asked: Why is the carotin when joined to protein sometimes blue, sometimes green, or sometimes red? This we do not yet know. Possibly a different variety of protein is concerned to make up each color. Nature may even make mistakes in this matter. A red lobster is exhibited alive at the London Aquarium just now, and I have seen a blue crawfish in a *vivier* in Brittany where they keep the catches alive until they are sent to the Paris market. At all events the carotin-protein dye can be formed very rapidly by the animals. There is a shrimp which turns blue regularly every night and loses the color again each morning. The formation of the blue color from carotin in the evening can be watched under the microscope through the shrimp's transparent skin.

Now that we know the chemical nature of the yellow and red colors of animals and of the lobster's blue, the next question to be solved is whence does the carotin come? Is it a waste product in the animal's economy, like the black melanin, the fishes' shining white guanin, or the butterfly's uric acid? Or has carotin in animals another source?

A slight digression must be permitted here. It is well known to biologists that living animals can be dyed artificially without injuring them. The two dyes most frequently used for this purpose are called methylene blue and neutral red. Transparent, colorless animals such as jelly-fish can readily be turned blue or red with these dyes while remaining in perfect health. Pigs, again, have been fed with madder, which gives their bones a pink color, and this procedure has been used to study the growth of bone. For if the madder is fed one day and not the next, the bone formed on the first day will show up as a pink layer. It has long been known that canaries become red when fed with red pepper. Both their feathers and the yolk of their eggs can thus be tinted, and even the skin of infants is said to take on a reddish tinge when they are given carrots to eat. Here then are definite cases of animals' borrowing a coloring matter from their food. Just as the jelly-fish were colored blue or red with dyes and the pig's bones were made pink by madder, so the canaries' feathers are stained with carotin, the coloring matter of red pepper.

Cattle Colored by Plants

One asks at once whether any other instances are known of carotin in animals that is borrowed from plants. A number of such cases have been proved. The yellow color of the fat of animals, for instance, is due to carotin. Experiments have been carried out to find whether the intensity of yellow in the fat varies or not with the feeding, and it has been found that this is indeed the case. The more plant food containing carotin that cattle get, the yellower becomes their fat. By withholding carotin from the food, — by giving artificial food, — the fat becomes paler in color. It is noteworthy that green food restores the yellow to the fat, and this is quite understandable in view of what has been said above of the quantity of carotin present in green leaves.

Thus many animals get their carotin, — or lipochrome, which is the same thing, — from their plant food; but there are other animals again which contain carotin, yet never eat plant food at all. They are entirely carnivorous. Is it possible that such creatures could borrow their yellow color? This does occur in certain cases of carnivorous animals, for they feed on other animals which in turn have got their carotin from their plant food. The following is a case which has been studied in detail. The Colorado beetle has yellow and red carotin in its integument. This it gets from its plant food. Now the beetle has a parasite called the stink-bug which preys on its young. This bug, too, is colored by carotin but steals it from its host, the beetle. The carotin of the parasite may be said to be not second- but third-hand.

It is evident, then, that in many cases animals do not manufacture their yellow and red coloring matter themselves. The plants do this for them, and the possibility then presents itself that perhaps all animal carotins are derived from plant food. Is there any evidence for this extreme view? Is no carotin at all manufactured by animals, but is it all second-hand?

Let us examine the case of the crustaceans again. Do crabs and lobsters also borrow their colors from plants? Straightway it may be said that if indeed they do so borrow their carotin, they must do so second-hand. They must behave like the stink-bug spoken of above, for these crustaceans do not eat plants at all. Most of them are scavengers and feed on the corpses of fish and shell-fish. Still, it would be possible for them to get their carotin in this way. Is there any evidence for or against this view?

When a dairy cow is made to fast the yellow color disappears out of the fat. The carotin returns only when more plant food is given to the cow. A crab, on the contrary, when made to fast loses none of its carotin. Here is a difference in behavior which is suggestive. Yet it in no way solves our problem. Let us attack it by another road.

In the crustacean, carotin is not diffused throughout the tissues as it is in fat or in the muscles of a salmon. The crab's carotin does not color all the cells, but on the contrary is collected in certain definite cells. These are star-like in shape and are called chromatophores. The chromatophores are scattered about among the other cells in the crab's skin, but they do not exist in equal numbers all over the skin. For the star-like cells with their carotin are found only on those parts of the crab which are exposed to light. That is to say, on the back and to a lesser extent on the sides. But they are absent on the under surface. What does this mean? Evidently that carotin is formed in the chromatophores with the help of light. Just as light is necessary to plants for the formation of their green chlorophyl, so it is a necessary factor in the production of carotin in crustaceans.

This being the case one can not suppose that the crab's and lobster's carotin is derived from plants. The animal makes it, with the help of light. It is quite evident, then, that while in many cases the yellows and reds of animals are borrowed plumage, in other instances animals manufacture their carotin for themselves.

The Reason for Yellow Coloring

What, then, is the meaning of this yellow carotin which we find so widely spread in plants and in animals? Does it play any rôle in the life of its possessors? Do the latter manufacture or borrow it for some definite purpose? Or is it quite useless to them? The carotin might have some most important function to perform. It might, for instance, be comparable to the red hemoglobin of the blood, which ferries oxygen from the lungs to the different parts of the body. Or it is conceivable that carotin could act in some way like the green chlorophyl of plants, with the help of which the plant makes sugar. Again, perhaps, carotin is merely a useless waste product. Is it in this way to be compared with the black melanin or the white guanin? In other words, is the yellow pigment a mere encumbrance to those which produce it or to those which are forced to absorb it with their food? These are all important questions to the physiologist, and questions which recent research has largely solved.

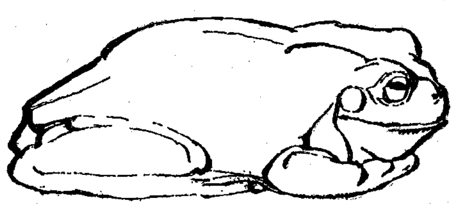
Petroleum and Amber

In plants carotin seems to be a true waste product. It is, as stated above, chemically a very simple body composed only of carbon and hydrogen. It resembles petroleum and amber in chemical structure, and these two are final breakdown products of plants. Carotin, too, appears to be of this nature. It is what the chemists call a very stable substance. In other words it is not easily altered or converted into something else. For this reason, when once formed, it stays unchanged and, when taken by animals with their food, it likewise passes without alteration into the living animal tissues. Carotin in plants, then, is to be looked upon as a by-product or an excretion. The plant does not want it but can not get rid of it. This does not mean, however, that it is never put to any secondary uses. The black melanin of animals is a stuff thrown away as it were, yet it may serve to form a black coat for concealment or for protection from the sun's rays. In just the same way carotin, although it is a by-product of the chemical works of the living plant, nevertheless like the by-products of many factories is used.

There are two principal uses which carotin is made to serve in the plant. In the first place, it acts as a screen to prevent injurious action of light. To make this clear, it must first be explained that the various chemical processes going on in the living plant are all of them speeded up by ferments. Sugar, for instance, is continually being oxidized, and this is what is called respiration. Now sugar can be oxidized in a laboratory only by being burnt. In other words, a very high temperature is necessary. Obviously this would be impossible in the plant, for the living substance would be destroyed by the heat, and so in the plant the high temperature is replaced by a ferment, which brings about the same result, and the sugar is oxidized. In the plant these essential ferments, or enzymes as they are called, are numerous. But it happens that these ferments are destroyed by too much light and particularly by the violet rays; and here carotin steps in, for it is just these violet rays that carotin stops. This is the reason why carotin is reddish-yellow. It stops the blue and violet rays of the rainbow colors into which white light can be split. When the blue and violet rays are stopped, the red and yellow remain, so that we see the carotin of these tints; and since carotin stops the violet, the latter can not harm the ferments.

This is one use to which the by-product carotin is put. The second use is of quite a different sort. As stated above, most of the red, orange, and yellow flowers owe their colors to carotin, but not all, for primrose yellow is a different pigment. Every one knows that the reason why flowers have colors is not to delight the eye of man but to attract insects. The plant has need of flying insects to carry pollen from one flower to another. This crossing gives hardier offspring. Carotin, then, in the flowers, subserves this task. It acts as a lure.

The animal, however, like the plant, can take advantage of its waste stuffs and utilize them. In numerous instances yellow skins make animals resemble their surroundings and so more easily escape their enemies. Others again seem to advertise their offensiveness by bright colors. Such are wasps and venomous snakes. Yet in other cases it is hard to see how the colors can be of any utility. Blue, green, and red crustaceans seem to lead equally happy lives in the sea, side by side with one another, although arrayed in such different hues.



Drawings by Silvia Baker

THE CHAOS CALLED COLLEGE

Need of Educational Values

George Thomas White Patrick

WHAT is wrong with our colleges? — a question often asked but seldom answered. Here Mr. Patrick approaches it in relation to the larger question: "What purpose should the college fill in the society of the twentieth century?" With our waning faith in Liberty, Equality, Democracy, Science, — the gods of nineteenth century Liberalism, — "our young people are very much at sea as to the sanctions of good behavior." It becomes the duty of the college, therefore, to create a new ethical consciousness.

IF it be true, as we hear so often, that our colleges and universities have lost contact with the actual "new world" in which we live, this has happened at a most unfortunate time. Never has the future of our Western culture been so uncertain, never have the time-honored agencies of social control, — civil law, custom, religion, — been so inadequate to check social disorganizing forces, never was educational guidance so necessary. There are many who believe that our civilization has outgrown the capacity of the human intellect to manage it. Increasing populations and constantly enlarging demands upon life do not make a safe combination. Social evolution has gone on with startling rapidity, but the development of intelligence has not kept pace with it, nor are we much encouraged in this respect by the falling birth rate among those classes where intelligence is marked. Our political problems have become so difficult that our legislative bodies are no longer capable of solving them. This has resulted in a loss of confidence in our congresses and parliaments and a resort to the rule of dictators and oligarchies. Since the War, in fact, there has been a general loss of confidence in those principles and institutions which scarcely two decades ago so many of us thought were to redeem the world, — democracy, efficiency, organization, applied science, invention, and discovery. In those days we were still under the spell of the nineteenth century with its identification of evolution and progress and its glowing faith in science. The increase of wealth, the mastery of the forces of nature, the conquest of disease were at last to relieve us from the "pain economy" of the ages and introduce us to the new "pleasure economy" of which we had long dreamed. The abolition of poverty also promised the dawn of righteousness, for the full dinnerpail would lessen the motives for crime.

Even now we can scarcely realize the extent of our disillusion-