THE ATHENIAN TRIREME.

The restoration of the Athenian trireme is one of the most important and controverted questions of archæology. The documents which may serve to solve it are numerous, and worthy of credence. Texts, inscriptions, and figured monuments have been discovered and described; the data gathered by savants, as evidenced by the beautiful work published by Mr. Cartault, increase every day; and yet no general solution has been found, and we are not certain as to the most essential point—the mode of propulsion. Sailors, in spite of books and images, deny the superposition of the rowers, and Hellenists affirm it under conditions that are contrary to the laws of mechanics and to the experience of men who follow the sea. Both put forth hypotheses that their adversaries have no difficulty in combating, and the discussion remains sterile.

An attentive examination of a bass-relief representing the central part of an *Aphraktos* trireme, found by Mr. Lenormant, at the Acropolis of Athens in 1852 (Fig. 1), has suggested to me a new method. Without pretending to an exactness that the subject does not admit of, I will describe a trireme of the fifth century, such as the texts and figured monuments show it, according to my opinion. The trireme was a very long boat with flat bottom and sharp form, and sitting low in the water, as the use of a large number of oars required. In the direction of the length, we find three divisions, to wit: in the center, a rowing chamber, wherein was concentrated the motive power; and in front and behind, a prow and a poop, whose space was devoted to different uses. In the direction of the height, the volume of the hull was divided into two parts by a continuous and strong deck.

Beneath the latter was the hold, and, above it, a half-open space limited by the upper deck—a light structure forming only a maneuvering flooring and shelter. The central part of the hull was divided into three parts: the middle, in which were stored water and provisions, and the two sides, which the Greeks called *thalames*, because they served as a refuge to the sick and to those who were wounded in combat.

The provision magazine was separated from the thalames by strong partitions (*diaphragmata*), which are mentioned in the texts, and concerning the role of which controversy has run rife. The rowing chamber was fitted up with two kinds of benches—the *thranites*, owing their name to the form of their supports, and the lateral or *zygites*, from their Greek name, *zuga*. All these benches, according to the texts, were immovable.

The figures show the details of these arrangements, and permit the method of the four kinds of rowing in vogue among the Greeks to be understood. In simultaneous or parade rowing the thranites, zygites, and thalamites were juxtaposed and interposed. The oars had but a limited sweep, and the purchase of the blades against the water was reduced.

In thranite or combat rowing the thranite oars alone were manned, and each of them was actuated by three men. The whole crew was employed; the rowing chamber was full; moving from fore to aft was forbidden, as also communication with the center of the hold; and the thalames were open to receive the wounded rowers. The speed of the galley attained its maximum. Being given its probable dimensions and the number of the crew as stated by historians, such maximum may have reached 10 kilometers per hour.

In zygite rowing, or that employed in urgent missions, the zygite oars, which were shorter and lower than the thranite, were manned and actuated by two rowers. The crew was divided into two sets, which relieved each other from time to time. The galley was capable of making 120 kilometers in 24 hours. The thranite benches were removed, and moving about was easy.

In thalamite rowing, or the method used in fine weather, only the thalamite oars were used, these being so light that they could be handled with ease by the youngest sailors. The rowers, who stood upright in the thalames, followed a slow rhythm; the crew was separated into three or four divisions; the propulsion was continuous; and the unoccupied sailors found rest and shelter in the rowing chamber, which had become free.

It is easy now to appreciate the ingenuity of the arrangements adopted by the Athenians to obtain all the advantage possible from the motive power; to understand the immobility of the benches, a feature so regrettable as regards the strength of the vessel; and to comprehend the parade

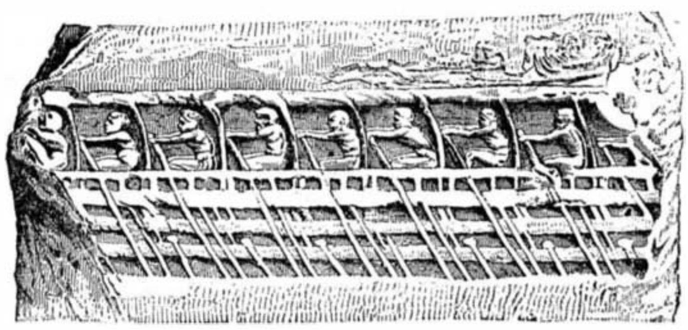


Fig. 1.—BASS-RELIEF REPRESENTING AN APHRAKTOS TRIREME.

rowing, which, moreover, had a useful purpose, since it permitted of ascertaining at a glance that the *materiel* and *personnel* were complete, and that the rowers had learned to row in unison and with accuracy.

The system of construction of the Greeks presented certain analogies with our own. The bottom of the ship consisted of strong timbers to which were attached the ribs forming the frame. Planks nailed to these ribs formed the shell and received the calking. The sides of the vessel

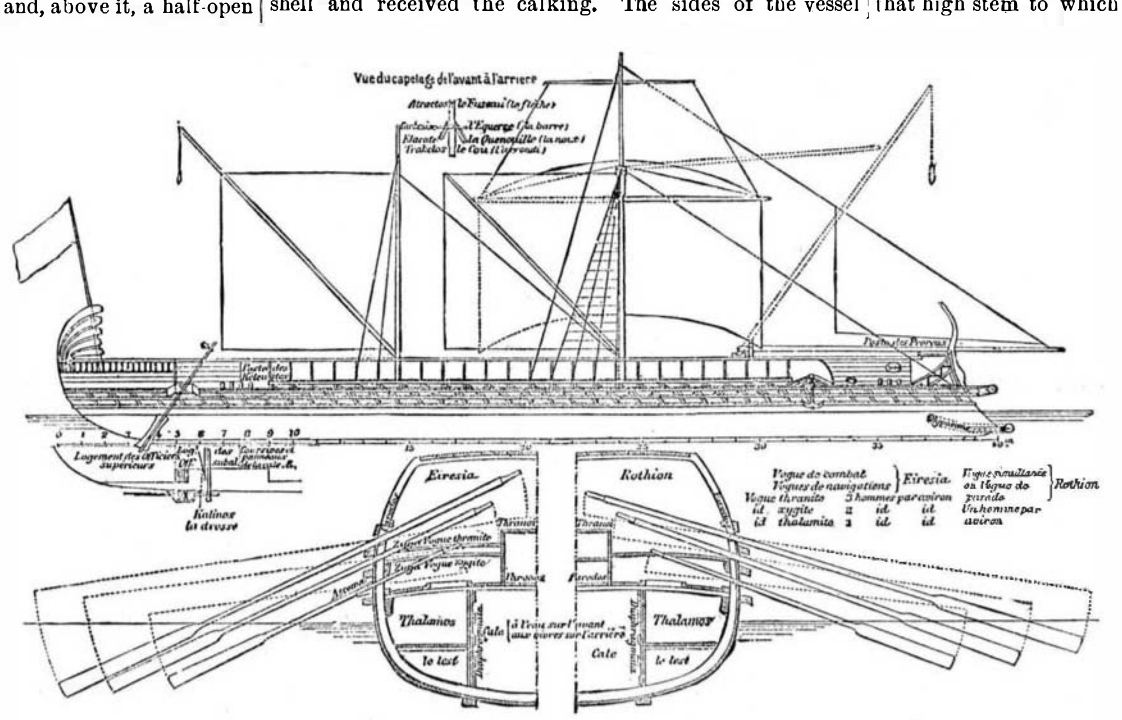


Fig. 2.—RESTORATION OF AN ATHENIAN TRIREME.

presented a very peculiar aspect, which is at once revealed and explained to us by the bass-relief from the Acropolis. Strong horizontal pieces ran along the side at distances that permitted of the passage of the oars. These ribbands or wales were connected by diagonal pieces running from top to bottom and from prow to stern. These ribbands and diagonals, which were connected by mortises, were bolted to the ribs and formed a covering of invariable triangles. It is very probable that the internal partitions of which we have spoken were also constructed of several planes of crossed wood, and that the purpose of the whole was to give the trireme, at the expense of a delicate workmanship and accurate measurements, a rigidity without which there could be no stanchness. The ribbands performed also another role; they served as defenses in boarding, and as bearing points for the *hypozomes*—the flat cables with which the trireme was enveloped, and the office of which was to deaden shocks.

Independent of the channel-wales, there were strong cinctures below the water line that ended, according to ancient figures, at the rostrum; and, above the gunwale, there was a double ribband, called *parodos*, consisting of two plankings nailed, one of them inside, and the other outside of the frame. It was within this interval, within this passage (which must not be confounded with the *parodos* that ran throughout the length of the rowing chamber, between the bench supports) that the Greeks deposited their shields.

Above the *parodoi* there were knee timbers designed for supporting the upper deck—this latter being a light platform serving as a place for maneuvering and fighting, and having beneath it, in front, the cable bitts and the cook's room, and, behind, the officers' quarters. Around these principal facts, which are known to us through texts or figures, are grouped secondary features.

We see the mainmast—the large mast that carried those square sails that are still used by small ships in the Archipelago, and that are so useful for sailing large or down the wind toward a mooring—and the two extreme masts, one of which carried the jib, and the other that lug sail which was so remarkable for its cut and rig. We find in the *stolos* that high stem to which the Mediterranean ships fix their studding-sail yard, and we imagine to ourselves the *proreus* standing upon the *akrostolion*, and leaning forward to question those below.

In front of the rowing chamber, and near the hawse holes (*ophthalmoi*), were the *epotides*—strong pieces of timber serving the double purpose of supporting the anchors, and protecting the oars when the enemy endeavored to break these by boarding lengthwise.

For this reason, these timbers were strongly braced by beams running backward and abutting against the ribbands, so as to form a sort of grating. Behind, there was a sort of fan whose curved blades were connected by the flagstaff. This was the *aphlaston*, which, although perhaps too much embellished, was certainly useful to the trierarch, who, from this open shield, watched the maneuvers of the enemy while running counter to him. Near by was the crosspiece which controlled the two rudders. These latter, which were conjugate, had the property (due to the arrangement of their bars) of revolving when pushed against; and their blades, which scarcely cut the water when the course was a straight one, dipped and sought of themselves more resistant strata when the pilot set them in action.

The trierarch's post was upon the upper deck, near the rudders, whence, through wide apertures, he was able to see the rear of the rowing chamber, and the *keleustes*, who transmitted his orders to the rowers. The mode of clearing the decks, and the maneuvers, were of the simplest nature.

The yards and square sails were deposited on shore, and the foremast was taken out and arranged for maneuvering the *delphins*. It is probable that these latter, not so heavy as the legend supposes, were metallic cylinders terminating in sharp cones, and guided in their fall by the cordage on which they had been hoisted. In falling, they acquired great penetrating power, and entered the deck just as the sharp-nosed porpoise enters the water after one of his leaps. The thranite oars were manned, the rowers being half naked. The thalamites had their shields at hand, ready, on fixing them in the parodos, to perform the maneuver that Jason taught the Argonauts. The defense of the rowing chamber was completed by leather curtains. The trireme bore down upon the enemy

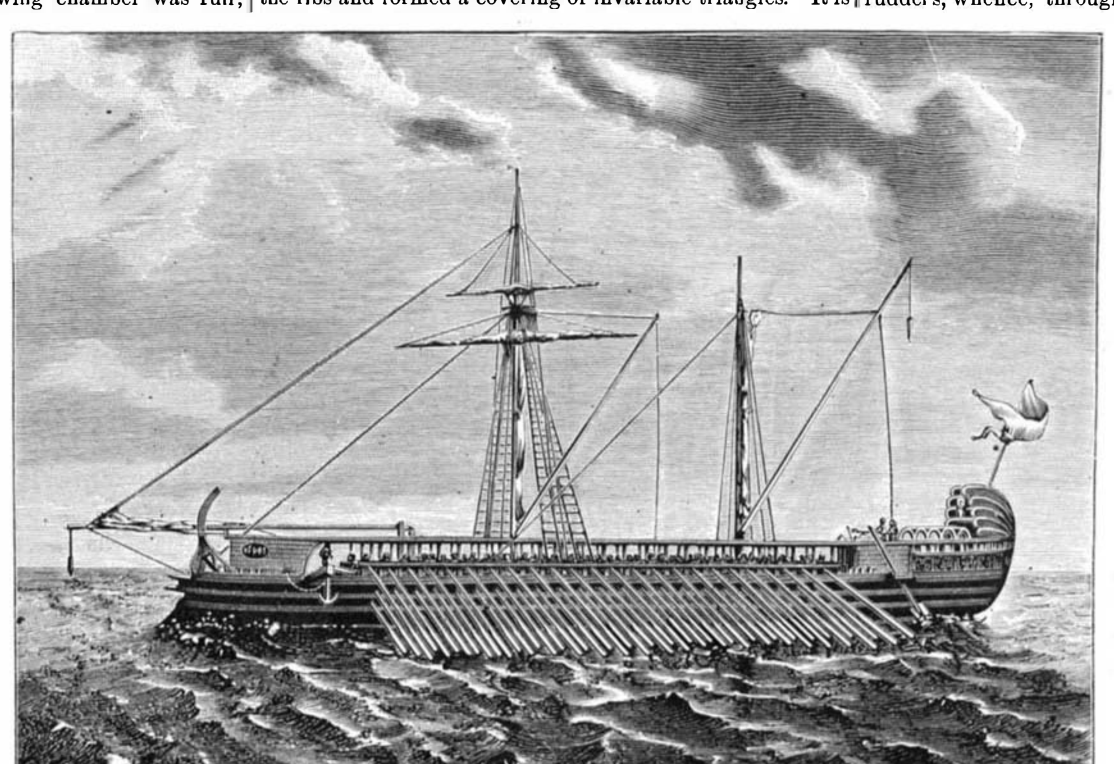


Fig. 3.—GENERAL VIEW OF AN ATHENIAN TRIREME.

and crossed him at a short distance; the soldiers and archers made use of their arms; and the oars on the side attacked were at once drawn in, their shanks slipping into their straps, and the handles, guided by the thranites, passing over the heads of the group on the opposite side, leaving nothing outside but the blades protected by the projecting *epotides*. If the distance permitted of it, the sailors let the delphins drop. The crossing effected, the oars were again actuated, and the trireme, thanks to her superiority in sailing and evolution, getting the better of her adversary, drove her rostrum into the latter's side.

We have designedly left till now a description of the rostrum and its accessories—the principal weapon of the trireme. This apparatus, which was placed very low, consisted of a bronze or iron fork whose branches were nailed to the longitudinal pieces of the prow, which latter was continued by a projecting rod and ended in a triple point. Thus outlined and attached, the rostrum did not penetrate so deeply as it would if it had had to attack less tapering surfaces higher up. There was less danger of its getting caught, and of thus exposing the vessel that carried it, and that had become immovable, to the attack of a second adversary; and the leaks that it opened were more difficult to stop. As an offset, if it had had to act alone, there would have been great danger of the trireme's being exposed to a dangerous strain through the action of transverse forces passing much beneath her center of gravity. This danger was warded off by the Greeks by means of the *proembolis*, which was a projecting piece forming a continuation of the channel wales, and armed with one or several metallic points. These latter came in contact with the surfaces above water almost at the same instant that the rostrum struck those below the water line. They struck into the planking or wales, prevented too deep a penetration, divided the frame timbers that tended to bend the beak, and annulled the action of that which tended to capsize the vessel. The utility of the *proembolis* was also very great during the course of a cruise; for by passing the hypozomes over its points, it became a safety buffer in cases of running afoul, and a protection for the cables. These precautions were not the only ones that the Athenians took against the dangers of navigation in squadrons. The points of the rostra themselves were sometimes trimmed with supplementary *hypozomes* offered by the expressed will of the people, that is to say, of the sailors. It must be observed that the intervention of such will was not an idle one, for the presence of submarine *hypozomes* rendered the work of the rowers very hard, and it was but just that those interested should be able to choose between fatigue and danger.

I have presented a general view whose parts are accurately arranged, whose details are borrowed from authentic documents that have been translated more or less freely, but always in the direction of practice and tradition. It is a solution which, by the fact alone that it is possible, seems to me ought to come near to the truth; and so I hope that this study will prove one step toward the restoration of a type that passed for a *chef d'œuvre* among a people of high culture, fond of an institution to which it owed glory, riches, and supremacy.—*Rear Admiral Serre, in La Nature.*

APPARATUS FOR REGULATING THE PRESSURE IN WATER CONDUITS.

The apparatus shown in the annexed Figs. 1 and 2 has been devised by a Mr. Eichenauer to deaden the shocks that occur in water conduits and to remove the air from the latter.

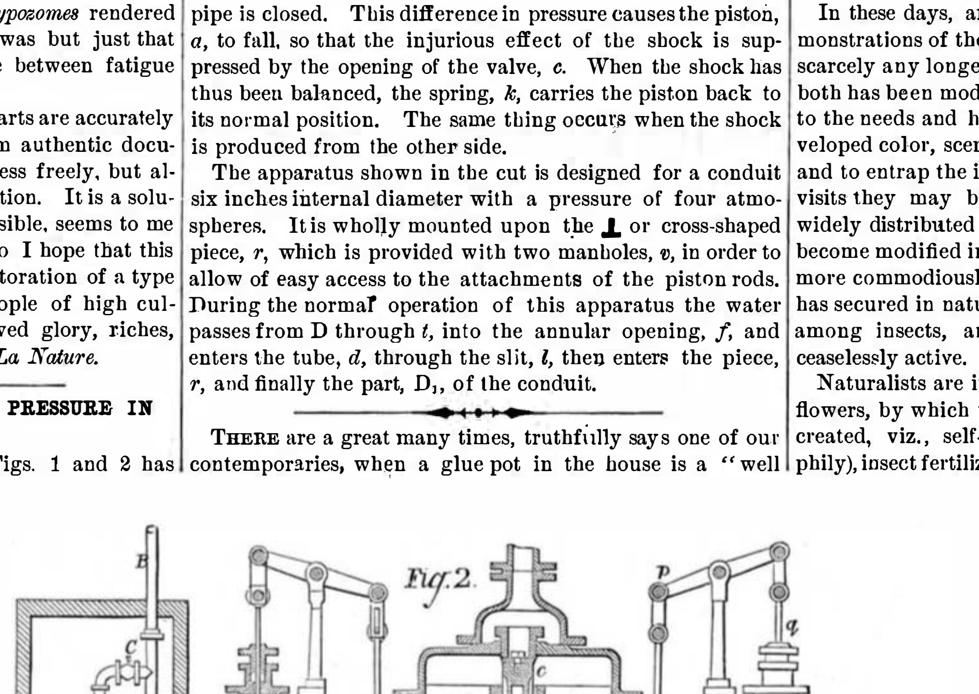
Referring to the plan, which is represented in Fig. 1, it will be observed that the apparatus, A, is placed at the side of the conduit, B, into the circuit of which it is introduced by opening the slides or valves, C_1 and C_2, and by closing C. This arrangement renders the apparatus accessible for repairs without its being necessary to shut off the water in the conduit.

If it is a question, for instance, of filling the empty conduit, B, with water, without the necessity of being obliged to open cocks or other apparatus in order to give exit to the air, the apparatus will operate as follows: The air, forced by the water into the apparatus at D in the direction of the arrows, shown in Fig. 2, through the channel, *g*, will be compressed in the cap, *h*, whence it may disengage itself through the valve, *c*, until the water, which has in the meantime entered the ⊥ pipe, *r*, lifts the floating piston, *a*, and thus closes the valve, *c*, which rests on the rod that guides it. Inversely, when a portion of the main water conduit is being emptied, the piston, *a*, falls with the water which is flowing out, and opens the valve, *c*, thus allowing a re-entrance of the air.

Any air that may accumulate in the conduit during its ordinary daily operations disengages itself in the same way automatically. As this air always flows to the highest points, it will collect in the cap, *h*, and finally, when its pressure has become greater than that of the water, depress the piston, *a*, and open the valve, *c*. There will thus be a constant equilibrium between these two pressures, and, besides, the air will prevent the water from rising too high in the pipe, *g*.

The injurious influence of the shocks that occur in main water conduits is prevented as follows: If, for example, the shock acts from the left, it will compress the spring, *k*, by means of the piston, *e*, and this spring being exactly regulated for a normal pressure, the piston, *e*, will in a certain measure close the aperture, *l*, in the tube, *d*, which serves as a guide to the said piston. At the same time the rod, *m*, by means of the bent lever or cam, *n*, will raise the rod, *o*, and depress the piston attached to *q*, thus closing the aperture, g_1. The shock is thus confined to the pipe, *g*, and to the cap, *h*, while the cross-shaped piece, *r*, and the part, D_1, of the pipe is closed. This difference in pressure causes the piston, *a*, to fall, so that the injurious effect of the shock is suppressed by the opening of the valve, *c*. When the shock has thus been balanced, the spring, *k*, carries the piston back to its normal position. The same thing occurs when the shock is produced from the other side.

The apparatus shown in the cut is designed for a conduit six inches internal diameter with a pressure of four atmospheres. It is wholly mounted upon the ⊥ or cross-shaped piece, *r*, which is provided with two manholes, *v*, in order to allow of easy access to the attachments of the piston rods. During the normal operation of this apparatus the water passes from D through *t*, into the annular opening, *f*, and enters the tube, *d*, through the slit, *l*, then enters the piece, *r*, and finally the part, D_1, of the conduit.



APPARATUS FOR REGULATING THE PRESSURE IN WATER CONDUITS.

THERE are a great many times, truthfully says one of our contemporaries, when a glue pot in the house is a "well spring of pleasure," and is an economical investment, especially when one of the kind here described: Buy at a tin shop one small tin cup, costing five cents, and a larger one, costing about ten, in which the smaller one can be set; five or six cents' worth of glue will mend a great many broken articles, or will fasten the things that have become unglued. Put the glue in the small cup with a little water; put boiling water in the larger one, and set the glue pot in it; in a few minutes the glue will melt and be ready for use.

NEW EXERCISING APPARATUS.

This improved exercising apparatus consists of a pair of horizontal parallel bars connected at one end by a third bar, and the three together supported by three legs suitably inclined and braced, one of them being under the center of the third or connecting bar and the others at the unconnected end of the parallel bars, said bars and legs being contrived to be easily taken apart and put together, and when taken apart are quite portable, light, and pack away in a small space. The apparatus is specially designed to afford the means in any room at one's home for the exercise known as "dipping," as practiced in the ordinary gymnasium.

This exercise, which, by the way, is a most beneficial one, consists in supporting the body upon the hands, which grasp the parallel bars, lowering the body by bending the arms until the chin is on a level with the hands, then raising the body by straightening the arms. This is repeated several times. The exercise develops the pectoral and triceps muscles very rapidly, and at the same time broadens and deepens the chest and throws back the shoulders, and has been highly recommended by authorities on physical culture; and for the want of suitable apparatus two chairs have been recommended, the chairs being placed back to back a short distance apart; but such device is so unsatisfactory that the exercise is generally neglected. This apparatus obviously overcomes all difficulties and affords entirely satisfactory means for practicing the exercise. An excellent exercise for the biceps and abdominal muscles may be obtained by grasping the bars from the under side and letting the body down toward the floor until the arms are straight, the legs, astride the back leg of the apparatus, forming a right angle with the body, and the knees kept straight, the raising the body by bending the arms until the shoulders are on a level with the bars, lowering again, and repeating several times. The exercise of dipping cannot be had from rowing-machines, health-lifts, or chest-weights. The nearest approach to it is found in the chest-weight; but they have to be permanently fixed in the room where they are used, while this apparatus, which is specially adapted for the exercise, may be set up for use when required and be readily taken down and put away when the exercise is over.

This useful invention has been patented by Mr. Geo. Worthington, of St. Denis, Baltimore Co., Md.

WORTHINGTON'S EXERCISING APPARATUS.

Flowers and Insects.

In these days, after the very elaborate and ingenious demonstrations of the relations of flowers and insects, it is scarcely any longer doubted that the intimate economy of both has been modified and adapted directly with reference to the needs and habits of each; that the flowers have developed color, scent, and intricate devices of form to attract and to entrap the insects, in order that by their propitious visits they may be cross fertilized, improved, and more widely distributed; that on the other hand the insects have become modified in shape and instincts to adapt themselves more commodiously to the various flowers, a process that has secured in nature a great variety of forms and habits among insects, and that these introactive influences are ceaselessly active.

Naturalists are inclined to think that the evolution of flowers, by which we now find three ways of fertilization created, viz., self-fertilization, wind fertilization (anemophily), insect fertilization (entomophily), has followed exactly this last mentioned order. That in earlier ages plants were all self-fertilized, that wind fertilized plants mark the next steps in advance, perhaps, and that insect fertilized plants developed their beauty of color and form last of all in the struggle for existence.

At this point, Mr. Ed. Heckel, a French botanist, enters a protest, contending that colors of flowers have not been evolved with any reference to the perceptions of insects. And he instances the brilliancy of the Alpine flowers, where he maintains there are no insects or too few to affect the results claimed by the evolutionists.

But recently M. Ch. Musset has spent four years of close observation in these altitudes, and affirms that insects are not absent or even rare at elevations of 7,000 feet above the level of the sea, and that the flower visitors, the Lepidoptera, Hymenoptera, and Diptera, were more numerous than the other orders. Further, the *comparative* rarity of insects at high elevations is exactly calculated to produce a sharper competition among the flowers, and lead to the production of more brilliant and conspicuous tints. M. Heckel still insists upon the insufficiency of the cause assigned, and of course he may be right, but the presumption is against him at present. His own explanation seems at any rate deficient, being that "the solar radiations are more intense than in the plains."

This might, it seems natural to think, affect the colors of the insects as well as those of the flowers, but they are as a rule somber and dark. At any rate, the brilliant skies of Persia, Arabia, and the Sahara have not produced a brilliant flora and fauna.