as fine black lines or bands cross-hatching what were previously the plane surfaces of the crystals. The fact that these black lines are really due to steps in the surface, can be demonstrated optically by examining them under light falling upon them at varying incidence, but a still more conclusive proof of their nature has been obtained by the production of an actual cross-section of surfaces upon which these lines or "slip bands" have been previously developed—these cross-sections were obtained by first imbedding the specimen of metal in a deposit of electrolytic copper, and thus protecting the edge of the original surface from injury during the subsequent sectioning process. In these cross-sections the fact that the slip bands are really steps, becomes unmistakably evident.

The microscopic study of metals has thus revealed an important fact in the microphysics of metals and of crystalline aggregates in general. The consequences of this generalization have as yet been worked out only in a few special directions. The most interesting of these is the application of the knowledge of the mechanism of deformation by slip to the explanation of the phenomena of fatigue in metals.

The phenomena of fatigue are, in their general features, so well known that we need only recall here the fundamental fact that under a load or stress which would be quite insufficient to break a given piece of metal if applied steadily and continuously, the same piece of metal will fail after a longer or shorter period of time if the stress be applied in an alternating manner, varying from compression to tension or even varying from zero to its maximum value. The researches of Ewing and Humfrey, subsequently extended and confirmed by the work of Stanton and Bairstow, have furnished the key to these, at first sight, surprising facts. The explanation is based on

the recognition of the mechanism of deformation in metals by the process of slip which was briefly outlined above. When a stress is applied to a piece of metal which is still far from sufficient to bring about a general plastic yielding, it may and in fact frequently does happen that owing to want of uniformity in the material or to want of uniformity in the distribution of the stress, a few of the crystals of the metal which happen to be unfavorably situated for meeting this particular stress, yield to it to a slight extent, and this yielding takes place by a small amount of slip occurring in these crystals. If the stress remains constant nothing further occurs, but if the stress be reversed the slip will also be reversed, and this repetition of slip, backward and forward over the same gliding planes, will recur with every alternation of stress. Now when such slipping occurs once only and to a moderate extent, it is sufficiently near the truth to say that the slip occurs without any disarrangement of the crystalline orientation of the molecules, but even then a certain very small amount of disarrangement occurs at the actual surface of slip—the mere rubbing of a piece of cloth over the surface of a piece of metal is sufficient to bring about certain molecular displacements at the surface and to set free temporarily some of the molecules near the surface, allowing them to rearrange themselves in new configurations. In the interior of a metallic crystal, therefore, where sliding occurs under great mutual pressure, some such displacement of molecules lying in or near the surface of slip must also occur.

If the slip only takes place once, the molecules thus disturbed are not only comparatively few in number but they rapidly rearrange themselves in the crystalline system from which they have been temporarily

disturbed; if, however, the slip be repeated, not only are the molecules first disturbed prevented from returning to their normal positions, but fresh groups of molecules are disturbed at each repetition, until the continuity of the material is locally destroyed and a fissure is formed—the material has, in fact, disintegrated itself by the continued friction on the surfaces of slip. Nor must this account of the disintegration process be regarded as speculative; the whole process can be followed step by step—the first occurrence of slip in a few isolated crystals and the gradual development of these slips into fissures, followed by the rapid spread of these fissures along the cleavage planes of adjacent crystals, has been followed by the aid of the microscope both in the case of practically pure iron and in steel of various kinds. Consequently it may well be claimed that the mechanism of the mysterious failure of metals under fatigue is now known and well understood.

Within the limits of the present paper it has only been possible to outline briefly and in very general terms some of the more recent achievements of microscopic study of metals and to point out here and there the obvious directions in which further discoveries are to be looked for. To attempt to prophesy the probable course of development of any branch of scientific investigation is always an extremely difficult task, but perhaps enough has been said to show that there is much yet to be learned from the microscopic study of metals. Some of the results to be anticipated are of a directly and purely practical nature; in other cases the lines of inquiry follow more scientific and theoretical directions; but even the most abstract of these questions bear in them—it may be confidently anticipated—the germs of practical applications of the widest importance.

HOW THE SNAKE USES HIS TONGUE.

IS IT A SENSE ORGAN OF DIRECTION?

BY G. R. O'REILLY.

How does the snake find his mate in the woods? How does he find his prey?

Thirty-three years ago I commenced to make a special study of the ways of snakes.

Anyone, who looks closely at a snake, will see that the moment the creature commences to move, he begins putting out his tongue, and keeps putting it out all the time he is moving. Startle him, and its movements become quicker, the tongue is put out oftener. Scare him well and he will keep it out, waving it in the air, for several seconds at a time. Why is this?

The tongue of the snake is long and narrow, and ends in a bifid or bifurcated tip; that is to say, it is divided near the tip into two long thread-like points. This long thread-like double-pointed tongue is not used for any of the purposes for which we use our tongues. It is not used in swallowing. It is not used in tasting as we understand it. It is not used in voice modulation. It is not used for licking.

What, then, is the tongue of the snake for, if it serves none of the ordinary purposes of the tongue?

I will answer this question shortly, by saying that its extremely sensitive points convey impressions to the consciousness of the snake. But this answer is too vague; it does not explain enough. To my mind the tongue of the snake is a sixth sense. It is similar, in a way, to the antennæ of an insect. It is a feeler, but it is more than that, as we shall see.

Before me, on the table now, is a cage about two feet long, having a glass front. In it is an ordinary garter snake, tame and accustomed to its cage. I take a live toad in one hand, and with the other draw the glass front to one side, opening it far enough to let the toad hop in from my right hand. As the snake first sees my left hand at the glass, he approaches it, expecting to be fed; while he never notices the right hand putting in the toad at the other end. Quickly I push the glass shut. The toad gives a hop forward in the cage, and remains still. The snake does not see the toad. His attention is attracted to my moving fingers pushing the glass back to its place. When I withdraw my hands, he runs his head along the glass from the left over to the right, where the toad entered. His tongue reciprocates inquiringly; but the moment its thread-like tips touch the spot on which the toad first rested, on entering the cage, the behavior of the snake instantly changes. He gets the trail of his prey. He ceases to nose the glass now. He pays no attention to me any more; he lingers over the spot the toad had touched; his tongue-points turn downward, darting in and out unceasingly. For some seconds he thus examines with his tongue tips the whole space on which the toad had rested. When he finds it is not there, he raises his head to look for it

elsewhere. His whole body now moves forward; and the toad, affrighted at this gliding terror, makes a jump, landing near a stone farther on in the cage. The snake catches just a glimpse of the quick motion of the toad, and makes a dart toward the place where he saw the moving object, but he fails to catch it. He did not see it perfectly, but he knows it is near, although he sees nothing; and now he becomes very earnest and busy in his search for it. He glides along, examining as he goes, with his tongue tips, the sides and bottom of the cage. The toad rests motionless within two inches of the stone, and yet the snake does not recognize it at rest. The snake comes to the stone, touches it with his tongue; no trail of the toad is on the stone, and he passes on. The toad knows it is not seen, and puts down its head to the floor. It lies there as still as death, for it knows instinctively, that in immobility lies probable safety. The snake passes over it; his belly touches its back as he glides onward, but never a sign of life does the cunning toad exhibit. Presently, the snake, getting no trace of the toad in the further end of the cage, returns. He draws near to the still, motionless batrachian. Aha! this time his tongue tips touch its head, whereupon the toad crouches down closer to the floor. The snake lingers, feeling it with his tongue tips; they tell him here is "toad flavor strong," so he pushes it with his nose to make sure; and the toad, knowing that its ruse of feigning death has failed, gives a jump. This is enough for the snake; he makes a lightning-like dart at it, seizes it, and swallows it quickly. Then he goes back to the spot where the late toad had rested, and examines the vicinity anew, to see if there might perhaps be another toad.

Now in all this proceeding of finding the toad, remember that the snake acts precisely as he would in the woods. He thrusts out his tongue, and touches with its tips every object he meets, till he discovers the trail of his prey. Then he becomes aroused, and looks around sharply. As toads do not travel far, he does not have long to linger over the trail before he sees the creature hop. The tragedy comes to an end by a lightning-like dart and seizure, just as it was done in the cage.

Now the question may be asked, do snakes actually take up the trail of their prey and pursue it in all its windings for considerable distances, using their tongue tips to guide them? To this the answer is that they undoubtedly do.

One instance occurred quite recently. I was sitting at an eastern window of my house in the woods, looking out through the fly screen at a blue-tailed lizard searching for insects among the small chips and bits of bark on the ground outside the kitchen door. The

kitchen forms an L from the house, so that I had a full view of the lizard, as he came out from under the kitchen by a pillar and passed within ten feet from the window where I sat. The lizard paid no attention to me, because I was inside the fly screen, and rested motionless, with my elbow resting on the window sill.

I noted accurately the path the lizard took. From the pillar he went to the east of one notable lump of bark, and then diagonally to another, which he passed to the west of, and then off to the other side through a little bunch of weeds, and from that to an empty packing box lying ten feet from me opposite the window. Under the packing box he went, and there he stayed. Casting my eyes toward the kitchen, I saw a blacksnake coming out, at the very same spot by the pillar from which the lizard had come.

He was on the trail, and never swerved from it an inch. He wiggled to the east of the first notable lump of bark, exactly the path taken by the lizard, and to the west of the next, then over to the clump of weeds, and then to the box, passing in, at the very same spot where the lizard had gone two minutes before. He went in under the box farther and farther, till half of him was hidden, and then, all at once, he began to draw himself out backward again. When his head came into view he had the wriggling lizard in his jaws. He swallowed him there and then before my very eyes.

I have seen a king snake trail a blacksnake and devour him in this very way.

Just as this blacksnake carefully trailed up and caught my blue-tailed lizard, so would he trace up and eat a young rattlesnake, if he found its trail in the woods. The gopher snake and the king snake do the same. I have seen them eating rattlesnakes as well as other snakes. I have seen the yellow-tailed South American gopher snake (*Spilotes corais*) trail up and eat a partly grown *fer de lance*, one of the most deadly snakes of the western continent.

The rock temperature in Bendigo mines, according to the report for 1907 of A. H. Marrin, chief mining inspector for Victoria, Australia, increases at the rate of 1 deg. Fah. for each 75 feet below the zone of invariable temperature. At 4,000 feet the temperature due to the heat of the rocks is 110 deg. Fah. At this depth the temperature of the water issuing from the rocks is 114 deg. Fah. Under average underground conditions, when there is water in the downcast shaft, the actual temperature in the stopes will be somewhere between 75 deg. and 110 deg. Fah., depending upon the quantity of air entering the stope and the length of time the air is in contact with the rock before entering the stope.