oak; and as the stem enlarges into a sort of tuber, the ants excavate galleries in all directions and establish therein their colony. The marvelous part of the matter is that, if the stem is not invaded by the ant, it fails to develop and the plant dies. The apparently abnormal tuber appears to be essential to the growth and maturity of the plant; and the ants—a small, red, and very fierce variety—aid in protecting the plant by making it unpleasant for anything which happens to disturb their dwelling.

The genus *myrmecodia* was formerly regarded as exclusively Malayan; but it is now known to be represented in Java and also in Australia. Five specimens of an Australian species are now growing at Kew Garden.

They have a slaty-gray color and greatly resemble wasps' nests. The galleries with which the tubers are intersected are lined by the ants with a thin papery material. Whether colonies of ants were imported with the plants, Mr. Britten does not say. The allied genus *hydrophytum* has a similar structure, and the best known species, *h. formicarium*, is tenanted by ants. There are three or four other species known, natives of Tropical Australia, the Fiji Islands, and the Indian Archipelago.

The next occurrence of the sort was observed by Aublet, and described in 1775, in his account of the plants of French Guiana. Aublet mentions two species of *triplaris* as inhabited by ants which acutely tormented him when he interfered with the trees in which they had taken up their residence. More recently Weddell, describing these trees, the trunk branches and even the smallest twigs of which are hollow and tenanted, says that, if one happens to touch the trunk of a *triplaris* accidentally, especially if it be shaken, the ants rush out by hundreds from the interior through the small canals by which the medullary canal communicates with the exterior; and if escape is not made quickly, the intruder is covered with dangerous guests, the bite of which is exceedingly painful. The Indians of Guiana call the *triplaris* the "ant tree," the tree being occupied by ants in every stage of its development. Weddell has found the tree, and suffered from the attacks of the ants, a clear brown variety, in many parts of Brazil, in Bolivia, and in Peru.

In the work already mentioned, Aublet describes also a shrub of the genus *tachia*, the stems of which, like those of the *cecropia* described by Belt, furnish bed and board for species of ants. The Galpis call it *tachia*, which in their language signifies "ant's nest."

The bases and petioles of the upper leaves of certain South American species of the genus *cordia* are similarly tenanted, so likewise are the leaves of a number of closely allied genera of *melastomaceæ*, all natives of South America. In these it is usually the petiole which has developed a form adapting it as a residence for ants. The following description, which Aublet gives of the mode of growth in the *tococa Guianiensis* will apply with slight modifications to all the other genera: The leaves are attached to the stems by a small hairy petiole, hollowed out into a groove on its upper surface and convex below. The two sides of the petiole swell out so as to form a double heart shaped bladder, corresponding with which are two holes on the under side of the base of the leaf, between the two intermediate nerves. Through these holes the ants have access to the divisions of the heart-shaped bladder. The stems, which are hollow, are entered by different openings. Mr. Belt describes a similar arrangement which he observed in an allied plant in Northern Brazil. A Mr. Trail, who is at present investigating this subject in Central America, writes to Dr. Hooker from Santarem, that at least three species of ants inhabit a melastomaceous plant of that region: he believes it to be *myrmodona formicaria*.

The manner in which the *acacia* known as the bull's horn thorn is tenanted and defended by ants in Nicaragua, as observed by Mr. Belt, was described in the SCIENTIFIC AMERICAN last summer.

In Honduras an orchid affords an equally satisfactory residence for ants. The hollow pseudo bulbs have a small hole at their base through which the ants enter; and so thoroughly do they take possession that Mr. Skinner, who discovered the plant, was almost prevented from collecting specimens by the stings of the swarms which rushed out upon him when he touched the plant. The orchidaceous plant referred to by Mr. Bates, "The Naturalist on the Amazons," in describing the formicarium of the Brazilian *crematogaster limatus*, was probably a relative of the one described by Mr. Skinner.

Now that attention has been called to the matter, it is quite likely that other partnerships of the sort will be discovered. Indeed Mr. Britten mentions several plants, specimens of which give evidence of such occupation. They are all South American species: a rubesaceous plant noreferred to *Remijia*; and two species of *hyptis*—*h. Salzmanni* and *h. calophylla*—which almost invariably present hollow swellings suitable for formicaria

MOLECULAR CHANGES IN METALS.

BY PROFESSOR R. H. THURSTON.

In a series of articles contributed to the SCIENTIFIC AMERICAN during the past year, the writer gave an outline of the various phenomena affecting the strength of metals used in construction, and described some that were peculiar in character and but recently discovered, illustrating these facts by graphic representions of the changes of resistance with change of form, such as were obtained by the automatic action of the autographic testing machine of the Mechanical Laboratory of the Stevens Institute of Technology. There are some phenomena which cannot be conveniently exhibited by strain diagrams; such are the molecular changes which occupy long periods of time. These phenomena, which consist in alterations of chemical constitution and molecular changes of structure, are not less important to the mechanic and the engineer than those already described. Requiring, usually, a considerable period of time for their production, they rarely attract attention, and it is only when the metal is finally inspected, after accidental or intentionally produced fracture, that these effects become observable.

The first change to be referred to is that gradual and imperceptible one which, occupying months and years, and under the ordinary influence of the weather, going on slowly but surely, results finally in important modification of the proportions of the chemical elements present, and in a consequent equally considerable change of the mechanical properties of the metal. The process of oxidation, or corrosion, is such a process, and is the most familiar one. Cast and wrought iron are both subject to it, the latter to, by far, the most serious extent. Cast iron is comparatively little affected by oxidation, even where exposed in wet situations or to alternate moisture and dryness. Wrought iron, under ordinary conditions of exposure, is said to become rusted to the depth of a sixteenth of an inch in a quarter of a century. In exceptionally trying situations, it corrodes far more rapidly. Steam boilers are sometimes rusted through, about the water legs, at the rate of a sixteenth of an inch a year, and instances have been known of even more rapid work that this. Exposure, however, while producing oxidation, has another important effect: It sometimes produces an actual improvement in the character of the metal.

Every mechanic knows that old tools, which have been laid aside or lost for a long time, seem to have acquired exceptional excellence of quality. Razors which have lost their keenness and their temper recover, like mankind, when given time and opportunity to recuperate. A spring regains its tension when allowed to rest. Farmers leave their scythes exposed to the weather, sometimes, from one season to another, and find their quality improved by it. Boiler makers frequently search old boilers carefully, when reopened for repairs after a long period of service, to find any tools that may have been left in them when last repaired; and if any are found, they are almost invariably of unusually fine quality. The writer, when a boy in the shop, frequently, if denied the use of their tools by the workmen, looked about the scrap heaps and under the windows for tools purposely or carelessly dropped by the men; and whenever one was found badly rusted by long exposure, it proved to be the best of steel. One of the most striking illustrations of this improvements of the quality of wrought iron with time has recently come to the knowledge of the writer. The first wrought iron T rails ever made were designed by Robert L. Stevens about the year 1830, and were soon afterward laid down on the Camden and Amboy Railroad. These were Welsh rails, and, when put down, were considered, and actually were, brittle and poor iron. Many years later, these were replaced by new rails, but until quite recently some still remained on sidings. When a lot of unusually good iron was wanted, some of these rails were taken up and re-rolled into bar iron. The long period of exposure had so greatly changed the character of the metal that the effect was unmistakable. These facts are stated by gentlemen upon whom perfect reliance may be placed.

"But," it will be asked at once, "how can such changes occur without apparent cause, however long the time?" There are probably two methods of improvement, each due to an independent molecular action. In the case of the razor and the spring, which regain their tempers when permitted to rest, it seems probable that a molecular rearrangement of particles, disturbed by change of temperature in one case and by alternate flexing and relaxing in the other, goes on, much as the elevation of the elastic limit and the increase of resisting power, discovered by the writer and shown on the strain diagram, takes place under strain and set. The other cases may probably be due to a combination of this physical change with another purely chemical action, which is illustrated best in the manufacture of steel by the cementation process. In this process, iron, imbedded in charcoal and kept at red heat, gradually absorbes carbon and becomes steel. Here the element carbon enters the solid masses of iron, and diffuses itself with greater or less uniformity throughout their volume. There seems to exist a tendency to uniform distribution which is also seen in a thousand other chemical changes. Many chemical processes are accelerated, checked, and even reversed by simple changes of relative proportions of elements, which compel acceleration or reversal as the only means of securing this uniformity of distribution.

When, therefore, wrought iron, containing injurious elements capable of oxidation, is exposed to the weather, the surface may be relieved by the combination of these elements with oxygen, and the surcharged interior, by this tendency to uniform diffusion, is relieved by the flow of a portion to the surface, there to be oxidized and removed. This process of flow goes on until the metal, after lapse of years perhaps, becomes comparatively pure. Meantime the occurrence of jarring and tremor, such as rails are subjected to, may accelerate both this and the previously described change.

The effect of strains frequently applied, during long intervals of time, is quite different, however, where they are so great as to exceed the elastic range of the material. The effect of stresses which strain the metal beyond the elastic limit has already been referred to in the SCIENTIFIC AMERICAN. The case of the porter bar (of which a sketch was given, showing how, after a long period of severe usage, it finally broke suddenly, exhibiting the peculiar fracture characteristic of such a method of rupture) will probably be remembered by many readers. A still more marked case has recently come to the notice of the writer

The great testing machine at the Washington Navy Yard has a capacity of about 300 tuns, and has been in use 35 years. Quite recently, Commander Beardslee, whose valuable work has been alluded to in this paper, subjected it to a stress of 288,000 lbs., but it subsequently broke down under about 100 tuns. The connecting bar which gave away had a diameter of five inches, and should have originally had a strength of about 1,000,000 lbs. Examining it after rupture, the fractured section was found to exhibit strata of varying thickness, each having a characteristic form of break. Some were quite granular in appearance, but the larger proportion were distinctly crystalline. Some of these crystals are large and well defined. The laminæ, or strata, preserve their characteristic peculiarities, whether of granulation or of crystallization, lying parallel to their axis and extending from the point of original fracture to a section about a foot distant, where the bar was broken a second time (and purposely) under a steam hammer. It thus differs from the granular structure which distiguishes the surfaces of a fracture suddenly produced by a single shock, and which is so generally confounded with real crystallization. This remarkable specimen has been contributed by the Navy Department to the cabinets of the Stevens Institute of Technology.

The somewhat similar instance of the dropping-off of the end of an immense shaft at the Morgan Iron Works, sometime since, while the opposite end was under the steam hammer, has been described in the SCIENTIFIC AMERICAN.

Were more conclusive evidence required of the occurrence of crystallization of iron, it has recently been given by an interesting incident at the Stevens Institute of Technology. A pupil, while annealing a number of steel hammer heads,

Fig. 1.

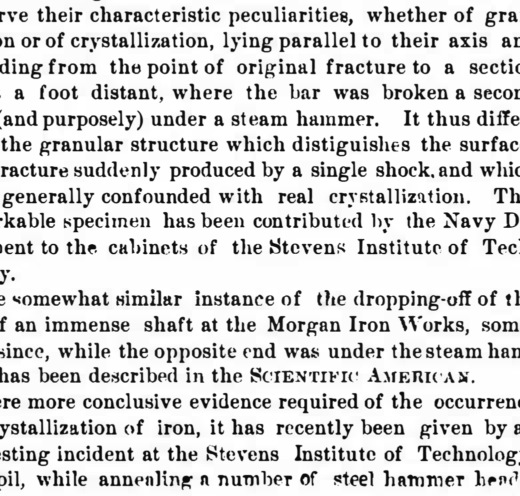

Fig. 2.

left them exposed all night to the high temperature of the air furnace in the brass foundery; when finishing one of them, a careless blow broke it, and the fractured surface was found to possess a distinctly crystalline character. In this example, however, the faces were all pentagonal, and were usually very perfectly formed. These illustrations are conclusive of the question whether iron may crystallize under the action of long continued and severe shocks, or of high temperature. When imperfect crystals are developed, it is easy to mistake them, but the formation of pentagonal dodecahedra, in large numbers and in perfectly accurate forms, may be considered unmistakable evidence of the fact that iron may crystallize in the cubic, or a modified, system. This may apparently take place either by very long-continued jarring of the particles beyond their elastic limits, or under the action of high temperature, by either mechanical or physical tremor. But no evidence is given here that a single suddenly applied force, producing fracture, may cause such a systematic and complete rearrangement of molecules. The granular fracture produced by sudden breaking, and the crystalline structure produced as above during long periods of time, are, apparently, as distinct in nature as they are in their causes. The broken hammer head is so beautiful and perfect an illustration, and such instances are so rare, that it has been drawn and engraved by the accomplished gentlemen attached to the SCIENTIFIC AMERICAN, and appears in this article as the first illustration of the kind which has appeared in the literature of engineering.

STEVENS INSTITUTE OF TECHNOLOGY, HOBOKEN, N. J.

Bacteria and Putrefaction.

Dr. Arnold Hiller, of Berlin, has made a series of elaborate experiments with the view of determining the relations of bacteria to putrefactive changes, and has come to the conclusion that the whole subject needs to be re-examined from the beginning. He has demonstrated that active putrefaction may take place in the absence of bacteria, and that bacteria may be present in abundance without giving rise to putrefaction. In short it seems quite possible that effect may have been mistaken for cause.

THE managers of the International Centennial Exhibition will promote the interests of the enterprise by establishing an agency in New York, and announcing the fact through the newspapers. A number of persons call at the office of this paper every day for information which we are unable to give.

A ONE track prismoidal railway is to be in operation by July 5, 1875, from Sonoma, Cal., to deep water in Sonoma creek, thus making communication by rail and water with San Francisco.