experiments. We have noticed that the long-continued "chipping" of cast iron with a chipping chisel will often cause the head of the hammer to break in two, especially if the hammer be not struck truly on the chisel head. Here we have a somewhat similar case to that of a wheel on a badly kept permanent way.

There is one very common form in which iron is used that is peculiarly favourable to the developement of this jarring action. The different links of a common chain or cable have a continual tendency, when in use, to rattle and strike against each other. The iron forming a chain is necessarily cut up into a number of different parts, which are often obliged to reciprocate each other's blows while the chain is performing its duty; and, in addition to this, chains are often exposed to sudden and powerful tensions. We thus find that the greater number of complaints as to structural alterations in wrought iron have pointed to chains. Mr. McConnell, while speaking on "Railway Axles and their Deterioration" at the Institution of Civil Engineers, 1850, mentioned that another striking instance of the conversion of tough wrought iron into a brittle material is shown in the chain slings used for carrying the bars during the process of hammering at a forge. "He had lately an opportunity of observing a chain which had been in use for this purpose, and had become so extremely brittle that it was more like glass in its fracture than the strong tough iron which it had been when first made; and he was satisfied that it had only been subjected to this extreme jarring action for a few months, and had not been otherwise applied." The chains used on inclined planes are also stated to break very soon. It is notorious that the crane chains used in engineer's shops almost always become brittle after being two or three years in constant use; their original condition is, however, restored by annealing. The chains used in drawing the "stuff" in the Cornish mines are generally withdrawn from the shaft after six months' use. They are then rolled in a heap, and covered with a sort of cylindrical furnace, and brought to a red heat. This operation is intended to do away with the effect of the vibration. Several of the witnesses before the 1860 "Select Committee on Anchors and Chain Cables for the Merchant Service," recommended a similar operation for the chain cables of ships, to be repeated periodically in conjunction with a system of re-testing. This deteriorating process in cables is so fully acknowledged by practical men, that Mr. T. M. Gladstone, in his evidence before this committee, even put a numerical value upon it, and stated that the chains of a light vessel which are constantly at work would deteriorate at the rate of 10 per cent. in two years. In ordinary cases, the deterioration of the iron would amount to 5 per cent.; and "it would be continuous, until the chain would ultimately break as short as a pipe stem." The instances we have cited are thus drawn from the experience of the work-shop, the forge, the mine, the railway, and from seafaring life; and the concurrent and universal testimony of those whose lives—daily and hourly—depend on iron, certainly points to the fact that iron is rendered brittle by vibration or undue tension, perhaps combined with other causes, such as deflection, or any sudden chilling through frost, or by contact, while heated, with cold water.

The theories propounded to account for these molecular changes in iron have been very varied and numerous. Until the experiments lately made by Mr. Kirkaldy on wrought iron and steel, it was generally assumed that a crystalline structure, like that of cast iron, was induced in wrought iron by means of its gradual deterioration through the causes mentioned above. Mr. Kirkaldy has, however, shown that a crystalline appearance is the invariable result when wrought iron is *suddenly* broken; when *gradually*, a fibrous appearance is the result. He appears to consider that this observation has settled the question—as a crystallized fracture can be induced in any iron, the crystallized appearance noticed in iron after it has been in use is merely due to its sudden breakage. Now, as all his experiments appear to have been made on new iron; "on pieces taken promiscuously from engineers' or merchants' stores, except those marked *samples*, which were received from the makers," the question as to the gradual deterioration of iron while under the influences of wear and tear is still as far as ever from a solution. It would, no doubt, be difficult to adduce "conclusive proof that the iron which is produced of a crystalline character was once fibrous." Perhaps the only way would be to subject a tested bar to a true percussive action through some time, and to then test the resulting diminution of tensile strain. The experience as to iron undergoing a gradual deterioration under certain circumstances is too universal to be discredited. The multitude of theories put forth to account for it bear witness to the fact, although an explanation of the phenomenon is still required. Mr. Hood, in the paper we have alluded to, ascribes the changes in iron to the conjoint action of "percussive heat and magnetism." Mr. Thorneycroft ascribes it to deflection. Some adduce magnetism alone as a principal cause; others point to the original impurities in iron, such as sulphur, phosphorus, arsenic, &c. Mr. Roebling, a distinguished American engineer, assums that the drawn-out fibre of wrought iron is "composed of an aggregate of pure iron threads and leaves, enveloped in *cinder*. Wrought iron thus becomes brittle under long-continued vibration under tension, "*because the iron threads and laminæ become loosened in their cinder envelopes.*"

There is no doubt, also, that the question has been complicated by many specimens being originally weak, either from defective quality or from being burnt in the forging. The fact seems to be that we are very ignorant as to the ultimate molecular structure of iron, or, indeed, of any other substance. Why does the presence of a per centage of carbon, more or less, exert such a mysterious influence on the cohesive powers of iron? We may never know much more about molecular structure until, in combination with experiments such as those of Mr. Kirkaldy, a powerful microscope shall have been used to investigate the structure of the specimens. It is difficult to believe that a change in tensile strength is not accompanied with a change in molecular structure. Robert Stephenson pointed to the use of the miscroscope for examining the differences in fracture of so-called crystalline and fibrous iron. He stated that,