for that year). After a period of neglect, it has been pursued with much energy by a large number of observers, and has yielded results which are of fundamental importance in relation to the strength of materials. For the purpose of microscopic examina­tion it is usually necessary to bring a small piece of the metal to a state of high surface polish, the final stage of which is per­formed by rubbing on a surface of wash-leather charged with a thin paste of rouge and water (see also Metallography). The specimen is then lightly etched in dilute acid or treated with a staining medium, such as liquorice or cocoa, to make the structure visible. When the surface is examined under a lens of suitable power it is seen to be made up of irregular areas with well-defined boundaries. The areas into which the surface is divided differ in apparent texture, and when illuminated obliquely it is found that some of them shine out brightly while others are dark; by changing the direction of the incident light other areas become bright and those previously bright become dark. These areas are the sections of crystalline grains which constitute the mass of the metal. Each grain is a crystal, the elementary portions of which arc all oriented one way, but the orientation changes as we pass from grain to grain. The irregular boundaries are the chance surfaces in which one grain meets another during the progress of its crystalline growth. Etching a polished surface develops a multitude of facets which have the same orientation over any one grain, and therefore give it a uniform texture and a uniform brightness in reflecting light of any particular incidence. The size of the grains depends very much upon the previous thermal treatment to which the metal has been subjected. Sudden cooling from a high temperature tends to make the grains small, slow cooling tends to keep them large; and protracted exposure to moderately high temperature has been observed in some cases to favour the growth of very large grains.

When the metal is strained in any manner beyond its limit of elasticity the grains are found to have altered their shape, becoming lengthened in the direction in which stretch has occurred. Subsequent exposure to a temperature which is high enough to remove the mechanical hardness produced by overstraining is found to bring about a reconstruction of the grains; the original pattern is not reproduced, but the reformed grains show no direction of predominating length. Researches by J. A. Ewing and W. Rosenhain ("The Crystalline Structure of Metals,” *Phil. Trans.,* 1900) showed that metals retain their crystalline character even when so severely strained as to exhibit qualities of plasticity which are at first sight inconsistent with the idea of crystalline structure. The manner in which a metal yields when the strain exceeds the elastic limit is by slips which occur in the cleavage or “ gliding ” planes of the individual crystals. These slips are seen under the microscope as sharply defined lines which appear on the polished surface of each grain as soon as the yield-point in any process of straining has been reached. Seen under normal illumination the lines are dark; seen under oblique illumination they may be made to appear as bright lines on a dark ground. The appearance of each line shows that it is a narrow step produced by the slipping of one part of the crystalline grain over another part. the diagram fig. 26 represents a section between two contiguous surface grains, having cleavage or gliding planes as indicated by the dotted lines, AB being a part of the polished surface. When straining beyond the elastic limit takes place, as by a pull in the direction of the arrows, yielding occurs by finite amounts of slip at a limited number of places, as at *a, b, c, d, e.* This exposes short steps, which are portions of cleavage surfaces, and which, when viewed under normally incident light, appear black because they return no light to the microscope. They consequently appear as dark lines or narrow bands extending over the polished surface in directions which depend on the intersection of that surface with the planes of slip. Many such lines appear as the process of straining goes on; they are spaced at more or less regular inter­vals, and in general three systems of them may be observed intersecting one another. With three independent systems of slips it is clear that the grain may take any shape in the process of straining; in many cases four systems of slips are seen. In this way severe deformations occur without affecting the crystal­line character of the structure, although the shape of each crystal undergoes much change. A bar of iron which has been rolled cold from a large to a small section shows, when it is polished and etched, a structure in which each grain has all the characteristics of a crystal, although the grains have been distorted into forms very different from those which are found in bars which are rolled at a red heat or are annealed after rolling. It appears that the process of straining has occurred through movements which preserve the parallelism of all the portions of each individual grain so long as continuity of the parts of the grain is preserved. In many metals, however, a further effect of severe strain is to develop twin crystals, and this implies a rotation of one group of elements through a definite angle with respect to the other elements of the same grain. Excessively severe straining, as, for instance, the squeezing of a block of lead into a thin flat plate, is found to produce a crystalline structure in which the grains have a greatly reduced size; the slips have in that case gone so far as to cause divisions and interpenetrations of the crystals.

*Growth of Crystals.—*Microscopic examination further shows that after severe straining the structure of a metal is far from stable, a fact which connects itself with what is observed in re­spect to mechanical quality. In some metals at least, and notably in lead, severe straining is followed, even at atmospheric temper­atures, by a protracted crystalline growth which results in the formation of crystals which are relatively very large. A piece of ordinary sheet lead shows the effects of this growth well; it will be found, when etched, to consist in general of crystals enormously larger than any that could have survived the process of manufacture by rolling. A similar growth may readily be traced from day to day or week to week in a piece of lead which is kept under observation after being severely strained. The process of growth is greatly accelerated by raising the temperature. That some process more or less analogous to this goes on in iron and steel during the change which occurs when elastic recovery takes place after overstraining may be conjectured, though there is as yet no direct evidence on the point. The growth of large crystals which is seen to occur in lead at very moderate temperatures has perhaps a more direct relation to the changes which occur in iron or steel at temperatures high enough to produce annealing. The structure of steel as exhibited by the microscope has received much attention, notably at the hands of F. Osmond and J. O. Arnold. Microscopic examination of the low or medium carbon steel used for structural purposes shows it to consist of grains of iron (ferrite), interspersed with grains which have in general a laminated structure and are composed of alternate bands of two constituents, namely, iron and carbide of iron (Fe3 C). To these laminated grains the name of pearlite has been given. In steel such as is used for rails, containing about 0∙4 or 0∙5% of carbon, the grains of pearlite occupy about as large a volume of the specimen as the grains of unlaminated ferrite; but when the proportion of carbon is increased to about 0∙9% the whole is a mass of pearlite having an exceedingly intimate mixture of the two constituents. This appears to be a eutectic alloy, and the same intimately blended structure is characteristic of eutectic alloys generally. Important variations in the visible structure result from quenching, annealing, and