INTRODUCTION.

The province of the Engineer and Architect is to control the forces of nature and apply them to useful purposes. The protection of life and property from destructive forces is accomplished by means of pieces rigidly connected with one another which transmit their action to bodies to which they are not injurious; while the utilization of such forces in moving weights, changing the form of bodies, and other similar operations is effected by a set of moving pieces which transmit their action to the required place and modify it in some given way. In the first case the pieces are called, collectively, a Structure and in the second case a Machine.

The actual form of a mechanical construction of any kind is almost always the final result of a process of evolution by which it has been gradually perfected by adaptation from some previously existing construction. To meet new wants the engineer selects some arrangement, suggested by experience of some nearly similar case, which appears likely to answer the purpose by its simplicity, facility of construction, and adaptation to the forces which it is proposed to control and utilize. If the new arrangement is merely a copy of the old this may be sufficient and the construction may be at once proceeded with, but if there be any important difference it is necessary, before incurring the expense and risk of actual construction, to ascertain that the design is in conformity with certain general principles which reason and experience alike show to be necessarily true in all cases. To a certain extent this has already been considered by the designer, but complete conformity can only be secured by comparison with results deduced by reasoning from those principles.

In any branch of knowledge the explanation of a set of facts by a general principle, from which new results can be obtained, is called a THEORY. When its principles are well established it enables us to predict the results of experiment; when they are not, it is even more necessary to direct the course which experiment should take for more perfect knowledge.

The systematic study of structures and machines with a view to discover the theoretical principles on which their construction is based, and the deduction from those principles of results which may be useful to the designer, forms a branch of science known as Applied Mechanics. In some cases, the subject may have been so exhaustively studied and may be in its nature so limited that all the arrangements which can be employed for a given purpose may be foreseen and the best determined by *à priori* considerations. The process of invention itself then becomes a problem in science. This, however, is the rare exception; in general, the use of theory is limited to the answering of certain questions relating to an arrangement which has already been proposed. Among the most important of these are—

(1.) What should be the dimensions of the parts of the construction that they may be strong enough to resist the action of the forces to which it is exposed?

(2.) Will the construction be sufficiently stable and rigid?

(3.) Are the natural forces which it is proposed to utilize sufficient for the proposed purpose and are they under proper control?

It is only in the very simplest cases that these and similar questions can be answered completely, without reference to the direct results of experience in order to interpret theoretical reasoning and render it applicable. Even, therefore, after the general plan of a construction is decided on, the work of the practical designer includes much which cannot be reduced to a mere process of deduction from given data. Nevertheless the part of theory in controlling and directing inventive power is of great and constantly-increasing importance, by furnishing principles of universal application, in conformity with which every mechanical construction must be designed, and by which the researches of the experimentalist must be guided.

The mechanics of structures and machines is based on the properties of materials, and on the laws connecting matter and motion the investigation of which, in their most general form, is the object of Abstract Mechanics, but the special nature of the subject matter occasions a certain difference in the methods employed. In purely abstract mechanics the number of bodies considered seldom exceeds two, and they usually possess a great degree of freedom to move; in applied mechanics a number of pieces are connected with comparatively little freedom. Further general principles, representing, approximately, the results of exact calculations or derived directly from experience, are admitted freely for the sake of simplification. The consequence of this is that the mathematical machinery employed is of a coarser type, and in particular, symbolical methods are in great measure superseded by graphical. The elementary principles of abstract statics, dynamics, and hydrostatics are supposed already known.

The classification of mechanical constructions depends in great measure on the number of pieces connected and on the mode of connection. We have first the broad distinction between structures, in which the pieces have no movements except such as may be due to changes in their form and dimensions consequent on the forces to which they are exposed, and machines in which the object is attained by means of such movements. This distinction is so fundamental that there is no word in common use which includes both.*

Structures may be ranged in order of simplicity according to the degree of constraint with which their parts are connected as follows:—

(1.) Structures with pin joints without redundant parts.
(2.) Structures with redundant parts.
(3.) Blockwork and earthwork structures.
(4.) Structures with riveted or other forms of fastened joints.

A pin joint is one in which the pieces connected are united by a single pin fitting into holes in the pieces, and, in consequence, the mutual action between the pieces connected necessarily passes through the axis of the pin. A redundant part is one which may be removed without destroying the structure if the remaining parts be sufficiently strong. The first class of structures therefore possess a peculiar characteristic which renders their theory much more simple than that of any other, namely, that the forces acting on each piece depend only on the external forces acting on the whole and not on

* The word "structure" is sometimes used in this wider sense.

the material or the dimensions of the pieces. In the theory of structures, then, this class is first considered, and the answer to the first of the general questions propounded above consists in the solution of two general problems.

(1.) Being given the load on the structure, it is required to find the forces acting on each part.

(2.) Being given the forces acting on a piece of material, it is required to find its dimensions that it may be sufficiently strong and stiff.

The first forms a part of the subject which may be properly described as the "Statics of Structures"; while the second, which depends on the properties of the materials of construction, is known as the "Strength and Stiffness of Materials." The results obtained are in continual requisition in the theory of the more complex structures, but require to be supplemented by additional principles, often derived from direct experience, peculiar to each class. The present treatise being simply introductory refers to the more complex structures only incidentally.

A Machine is a structure the parts of which are in motion. The motion introduces new forces, often of great magnitude and importance, which must be taken into account in its design; but we have, in addition, to consider the third general question mentioned above, namely, the adaptation of the natural forces available, to the work which the machine has to do. The simplest machines consist of a number of rigid pieces, and their theory is divided into two parts, one concerned with the motion of the machine, the other with the work it does. Since the parts of structures as well as machines possess, though to a very limited extent, freedom to move, and since such movements often have to be supposed for the purposes of an investigation, the natural arrangement would be to commence with the first part of the theory of machines and then pass on to the statics of structures. It has, however, been found convenient to invert this order and we now, therefore, commence with structures.