

bottom chords of the truss, and as the floor framing was built up, the traveler moved forward over it. Across the top of the front bent of the traveler was a strong, transverse lattice girder, at the center of which was pivoted the 62-foot boom of the derrick, and the foot of the derrick mast. The two stiff-legs were carried back to the last bent of the traveler as shown, and when a heavy load was to be lifted, the bottom frame of the traveler was clamped to the upper flanges of the floor stringers.

The material for the floor system was brought on scows to a landing near the foot of the towers, hoisted on to a tramway, run out to the front of the base of the towers, and then hoisted to the level of the floor system by a crane which placed it on a trolley, the trolley in turn carrying it out to the erecting traveler on the bridge. The chords were built out in 60-foot sections, representing each a length of three panels, the weight of each section being 25 tons. The floor beams, which were the next heaviest single load, weighed 10 tons each. As soon as the 60-foot chord lengths with the floor beams and stringers between them had been bolted up, the traveler moved forward 60 feet, and another section of the floor was built out, the operation being repeated until the two gangs of workmen met at the center of the span. The whole 1,600 feet of floor, weighing no less than 2,750 tons, was erected and bolted up in six weeks' time, a most creditable performance, and a rate of speed which, if it had been observed on some other portions of the work, would have hastened the final completion of the bridge materially. The next operation was to erect the 50-foot stiffening trusses, the lateral carrying trusses for the floor beams, and the various details of the lateral wind truss system. Sec-

anchorage stands on the natural sand. There are 12,000 tons of steel in the towers and shore spans; 5,000 tons of steel wire and cable castings; 18,000 tons in the steel approaches; and 8,000 tons in the suspended structure of the main span.

The contract prices were as follows: New York tower foundation, \$373,463; Brooklyn tower foundation, \$485,082; the anchorages, \$1,570,000; steel towers and shore spans, \$1,221,726; cables and suspenders, \$1,398,000; the approaches, \$2,411,000; the main span suspended system, \$1,123,400. The total cost of the Bridge, including land, is over \$20,000,000.

The Engineering Staff.

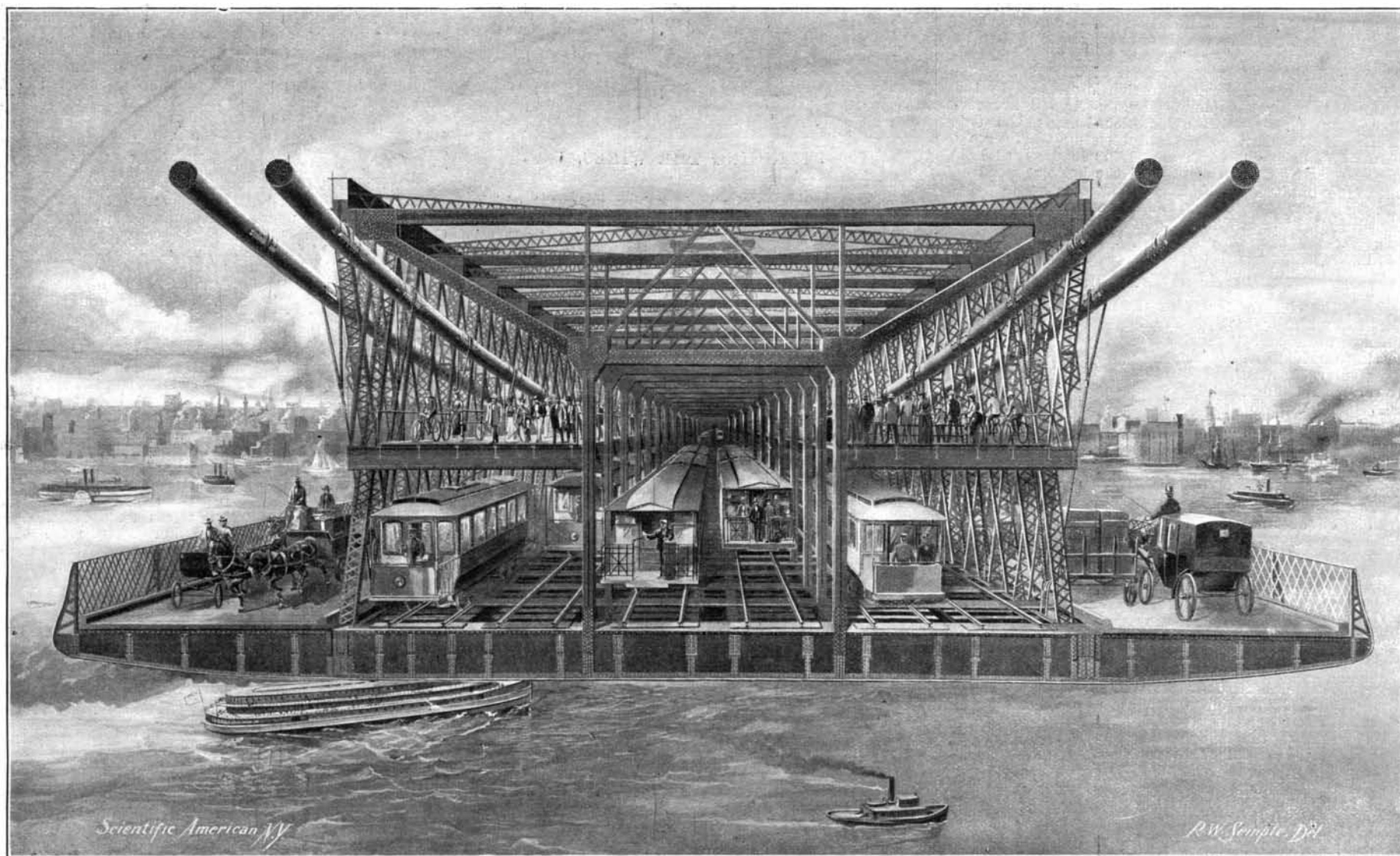
In concluding our description we take pleasure in bearing testimony to the unvarying courtesy of the engineering staff in giving the SCIENTIFIC AMERICAN every facility, during the erection of the bridge, in preparing the many illustrated articles on the subject that have appeared during the past seven years. Mention should be made of L. L. Buck, the chief engineer; O. F. Nichols, principal assistant engineer; H. D. Robinson and K. L. Martin, resident engineers, in addition to others who are mentioned incidentally during the preceding article.

MECHANICS AS EXEMPLIFIED BY THE ANIMAL FRAME.

By PROF. DR. OTTO FISCHER.

FROM man's earliest knowledge of it, physiology, organic and inorganic, has furnished the greatest variety of mechanical problems. For instance, it furnished the incentive to mechanical respiration, mechanical diges-

tween neighboring parts of the body, as well as concerning the joints themselves and their possible motions. The human and animal bodies have often been compared to machines. In the joints, however, it is already shown that they differ materially. On the one hand, we have in the animal body joint-surfaces which are to a certain degree deformable, i. e., subject to enforced change, since the articular ends of the bones in the larger joints of the human frame are covered with a cartilage up to a thickness of 5 millimeters, which is deformed, or suffers compression, under a load; whereas in a machine the joints are purposely made very strong and of the material best calculated to withstand the wear without give or loss of motion. Again, there is much greater freedom in the movements of the joints of the human and animal frames. Since the purpose of most mechanical joints consists in forcing, by the form of the joint, the surfaces of the two connected parts to move in a determined relation to each other, the difference in the animal organism is more apparent, because in most of the joints no such compulsion is present, at least not in the form of the joint itself. As is well known, in both the shoulder and the hip joint we are able to move our extremities in the greatest variety of ways toward the trunk. The difference of the two combinations is more patent when we consider the relative motions of two separated parts, parts not joined directly together. In a machine, even parts of the organization widely separated are compelled to move in a previously determined relationship one to the other, whereas in the human organism, the further the parts are separated, the greater the freedom of movement. For example, the movements of the hand, within the limits pre-



Roadway. Bicycle track. Footway. Footway. Bicycle track. Roadway.
Surface cars. Elevated cars. Surface cars.
Extreme Breadth, 118 Feet. Depth of Trusses, 40 Feet. Length of Main Span, 1,600 Feet.
THE FLOOR-SYSTEM OF THE NEW EAST RIVER BRIDGE.

ond only in importance to the erection and bolting up of the floor and truss was the work of riveting, which followed close after the first erection. For riveting, an air-compressing plant was built on the Brooklyn shore, and a 6-inch main was laid across the bridge.

To facilitate erection, and to insure that when the final riveting up took place the bridge would hang at its proper designed curves and level, the contractors drew up a blue-print showing where the material of the trusses and lateral system was to be placed along the bridge ready for erection. Every one of the many thousands of angles, posts, girders, etc., was numbered, and had its place assigned it somewhere on the great 1,600-foot span. Each piece was laid upon the floor in the reverse order in which it was required, so that when the erectors started work there was no time lost in hunting for particular sections, but they were right at hand ready to be put in place, and incidentally performing the important function of loading the flexible structure to the true lines, in which it was inflexibly held when the stiffening truss had been erected and riveted up.

Figures of Quantities and Cost.

An account of this great structure would be incomplete without some statement of the great quantities and cost of the materials of construction. In each anchorage there are 1,500,000 cubic feet of timber, 10,000 cubic yards of concrete, 45,000 cubic yards of stone masonry, and 1,700 tons of anchor steel. Beneath the Manhattan anchorage are 3,500 piles; the Brooklyn

tion, mechanical circulation of the blood, a mechanical development wherein, of course, the mechanical conception is, in part, endowed with a more general philosophical meaning.

Physiology has, moreover, not only taken counsel of the science of mechanics in the explanation of the bodily form, and many arrangements in the structure, at certain periods of plant and animal organism, but also for the better understanding of the functioning and capacity for work of the same.

The principal field for the application of mechanics in physiology is, at all events, the study of the limb-movements of the human as well as other animal bodies, be it that the same are applied to locomotion or to the accomplishment of other forms of work. Physiological mechanics, in the above-described restricted sense, finds the subjects for its inquiry already prepared in nature. But before it can advance to the investigation of the movements of the living body, impelled by external or internal forces, more especially muscular force, it must acquire a precise knowledge of those peculiarities of the individual parts of the body, which, above all, characterize the mechanical relation of the parts to the motive force.

In the beginning it is necessary to determine such quantities as the dimensions of the body, its weight, the center of gravity, and the so-called moment of inertia, which depends upon the division of the mass about the center-point; all these items are applicable to the living body. Furthermore, there must be made a thorough search into the manner of articulation be-

scribed by the length of the bones of the arm, are carried on toward or from the trunk as if it were free from the body altogether.

In spite of this apparent freedom from restraint, we are nevertheless in the position to command at any moment a certain movement of the part. This compulsion is not forced upon the hand by the form of its joint at the shoulder or the elbow, but by the governing force, *our will*, transmitted to it by the way in which we excite the muscles connected with the joints. We are able therefore at any moment to change our body at will in the greatest variety of ways, into a certain machine.

From this viewpoint the human body resolves itself into a machine of the greatest versatility; a great complex of different machines. That this versatility is not gained at the cost of perfection in the mechanical performance of the individual acts, is a matter of daily experience.

The radical difference between the organic and mechanical joints affords the kinematic investigation of physiological mechanics, as far as it relates to the articulation of the joints, its characteristic stamp; it demonstrates that we not only find a much greater variety in the forms of the articular surfaces of the organism, but that we are also capable, at times, of movements in an organic joint that would be utterly impossible in a joint of stiff, unpliant metal.

The chief problems of physiological mechanics have to do with the exercise of motion by the members under the influence of exterior or internal forces. These

kinetic problems are divided into two groups. In the first group, the powers or forces are accepted as known, and the problem for solution concerns the motions which these forces create in the living organism. Under this head, and above all others, belong the researches into the effect which the single muscle of the human or animal body exerts by its contraction at a certain determined tension. As valuable as these inquiries may prove for the more perfect comprehension of the function of the individual muscles, as far as physiology is concerned they possess more of a theoretical than a practical value, for up to the present it has neither been possible to determine the tension of a muscle in the living body nor to estimate its contractive powers under electric excitement.

The second group of kinetic problems for physiologico-mechanical solution presupposes the condition of mobility in the living body during the course of the motion, and inquires into the muscles which, in conjunction with internal forces, cause the motion.

These tasks, in which occur also purely static problems that refer to the complete quiescence of the human body, are of considerable value to physiology.

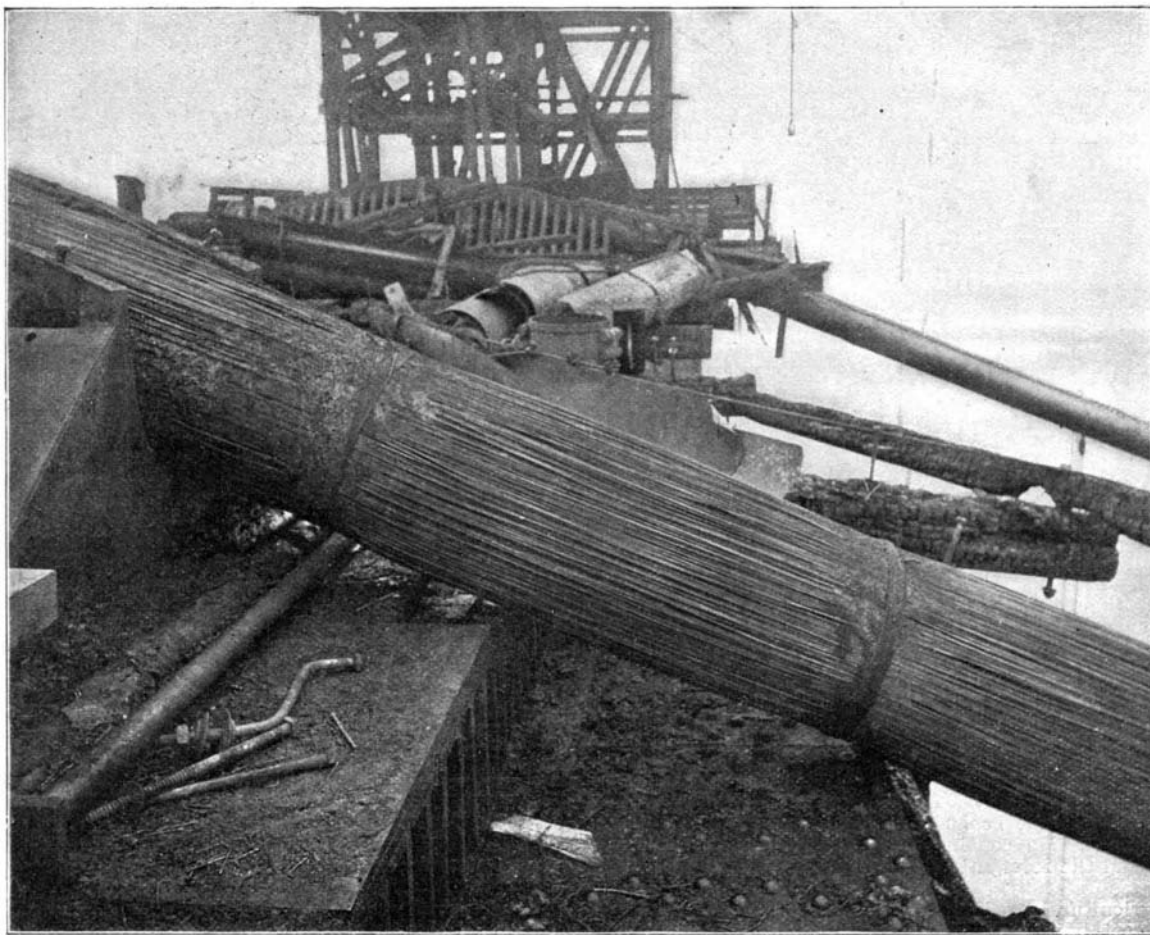
While the solution of problems under the first group often presents insurmountable difficulties, those of the second group are always solvable in principle as soon as the condition of motion of the body for the whole course of the motion to be examined has been empirically determined with sufficient exactness. To this end instantaneous photography renders invaluable services. For a kinematic analysis of any given motion of the human or animal body it is sufficient to fix, as closely as possible, the superficial motion of single suitably chosen points of the different parts of the body. This is best accomplished by making these points intermittently self-luminant by means of electricity. For this purpose there may be arranged on the desired points of the body a line of wire severed at many places, which will produce sparks, or small Geissler tubes, having a current from an induction coil

passed through the whole. The necessary interruption of the current may be effected by means of a tuning fork, which will make and break the current at exact intervals of time.

To carry the investigation further, provide a totally dark room in which the subject shall be placed, and from any number of sides let the motion with its il-

ferent points. There remains now only the exact measurement of the series on each plate in order to transfer the whole procession of motion to a superficial chart or system of co-ordinates, and upon the basis of this co-ordinate system undertake a kinematic analysis. The problems of the second group which have so far been taken in hand relate mostly to the progression of man or animals. Those studies which relate specifically to the progression of man come down to us from the investigations of the brothers William and Edward Weber. They were the first to fix, as exact as possible, with the means at their command, the laws relative to the various gaits, walking, running and jumping. Since instantaneous photography, then unknown, could not aid them, they were compelled to supplement the results of their measurements with many hypotheses. Upon this basis they nevertheless built up their theories of the walk, the double-quick, and the lope, which afford at least a passable representation of the kind of external forces that influence the motion of the common center, and also of the mutual effects of the trunk and the extremities upon each other. Because the character of their kinematic theories was all too hypothetical, and they have of late proven themselves untenable, they were unable to proceed with the examination of the activity exerted by the individual muscles. At all events, the Weber "Mechanics of the Human Walking Organs" stands as the first attempt to explain the special sequence of motion of the human body through the exact means of mechanics—

Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from Prometheus.



SUMMIT OF THE MANHATTAN TOWER, SHOWING INJURED PORTION OF ONE OF THE MAIN CABLES.

luminated points be photographed by a number of ordinary cameras at the same instant. This can be done without attaching any expensively constructed shutters to the camera, for the points are all illuminated at intervals equal to or less than those provided by the quickest shutter, being at the same time continuous. Since in this case the interruption of the exposure is, to a certain extent, placed in the object itself, we obtain for the kinematic analysis absolute isochronism in the series of pictures taken from dif-

ferent points.

REPORT OF THE SECRETARY OF AGRICULTURE.

THE annual report of the Secretary of Agriculture has been published. It begins with a discussion of the educational requirements of the research work of the department. Although the department has availed itself to the fullest extent of graduates of the agricultural colleges, it has been necessary, in view of the



THE NEW EAST RIVER BRIDGE AFTER THE FIRE. THE MANHATTAN TOWER WHERE THE FIRE OCCURRED IS IN THE FOREGROUND.