the heavenly bodies. Its basis is precisely of the same character, the coincidence of the observed facts with theoretical requirements."

Leaving these authorities on the doctrine of evolution, I will now give you a sketch of LaPlace's (1780) nebular theory, epitomized from Spencer's "Progress; Its Law and Cause:" "If this hypothesis be true," says Mr. Spencer, "The Genesis of the solar system supplies one illustration of this law. Let us assume that the matter of which the sun and planets consist once existed in a diffused form, and that from the gravitation of its atoms there resulted a gradual concentration. By this hypothesis the solar system in its nascent state existed as an indefinitely extended and nearly homogeneous medium—a medium nearly homogeneous in density, in temperature, and in other physical attributes. The first advance towards consolidation resulted in a differentiation between the occupied space which the nebulous mass still filled, and the unoccupied space which it previously filled. There arose in this state or condition a contrast in density and a contrast in temperature, between the inside and the outside of this mass, and as a constant property of matter is motion, there arose throughout the volume rotary movements, whose velocities varied according to their distances from its center. These differentiations increased in number and degree until there was evolved the organized group of sun, planets, and satelites which we now know. A group which presents numerous contrasts of structure and action among its members. There are the immense contrasts between the sun and the planets in bulk and in weight, as well as the subordinate contrasts between one planet and another, and between the planets and their satellites. There is the similarly marked contrast between the sun as almost stationary and the planets as moving round him with great velocity, while there are the secondary velocities and periods of the several planets, and between their simple revolutions and the double ones of their satellites, which have to move round their primaries whilst moving round the sun. There is yet the further strong contrast between the sun and the planets in respect of temperature; and there is reason to suppose that the planets and satellites differ from each other in their proper heat as well as in the heat they receive from the sun." Now, how is this heat generated, and how is it kept up? There is the theory known as the meteoric theory of the sun's heat. Tyndall says: "Knowledge such as we now possess has caused philosophers, in speculating on the mode in which the sun is nourished and his supply of light and heat kept up, to suppose the heat and light to be caused by the showering down of meteoric matter on the sun's surface." This is Meyer's hypothesis, worked out in 1848.

What foundation is there for this hypothesis? That heat is generated by motion, friction, compression, and percussion Tyndall gives an experiment in one of his lectures. He cools a razor by contact with ice, rubs it on a hone without oil, as if to sharpen it; he places the razor against the face of a sensitive pile with a needle attached which marks slighter variations of temperature than the ordinary thermometer. The audience sees a powerful deflection of the needle, which declares the razor to be hot. To prove heat by compression he places a piece of deal wood between the plates of a small hydraulic press and squeezes it forcibly; after compression he brings the wood in contact with the pile, which declares *heat* has been generated by compression. To produce heat from percussion he takes a *cold* lead bullet, places it on a *cold* anvil, and strikes it with a *cold* sledge hammer; examine the lead and it is heated; and says: "If we could gather up all the heat generated by the stroke of the sledge and apply it without loss mechanically we should be able by means of it to lift the hammer to the height from which it fell." Now, what proof have we for that? Dr. Meyer, of Heilbronn, in Germany, enunciated the exact relation which subsists between heat and work, giving the number which is now known as the mechanical equivalent of heat. Mr. Joule, of Manchester, independently of Meyer, experimented to prove the invariability of the relation which subsists between heat and ordinary mechanical force. He placed water in vessels, agitated that water by paddles driven by *measurable forces*, and determined *both* the *amount* of heat developed by stirring the liquid and the *amount of labor expended in the process*. He did the same with mercury and with sperm oil. He also caused disks of cast iron to rub against each other, and measured the heat produced by their friction *and the force expended* in overcoming it. He urged water through capillary tubes and determined the amount of heat generated by the friction of the liquid against the sides of the tubes. This is a delicate experiment.

"The results of his experiments," says Tyndall, "leave no shadow of doubt upon the mind that, under *all* circumstances, the quantity of heat generated by the same amount of force is fixed and invariable." Again, Count Rumford, while boring a cannon at Munich in 1798, was so forcibly struck by the amount of heat developed in the process of boring that he contrived an apparatus for measuring the amount of heat generated by friction. He constructed a hollow cylinder of iron, filled the cylinder with 18¾ pounds of water at 60°, caused the bottom of the cylinder to be pressed against the part of the cannon where friction was greatest. An hour after the friction was commenced the temperature of the water was 107°; the second hour it was 142°; at two hours and thirty minutes after the commencement the water actually boiled. By these and numberless other experiments it was found that the quantity of heat which would raise one pound of water one degree in temperature is exactly equal to what would be generated if a pound weight, after having fallen through a height of 772 feet, has its moving force destroyed by collision with the earth. Conversely, the amount of heat necessary to raise one pound of water one degree in temperature would, if all were applied mecanically, be competent to raise a pound weight 772 feet high, or it would raise 772 pounds one foot high. Thus the quantity of heat necessary to raise the temperature of a pound of water one degree being taken as a standard, 772 foot pounds constitute what is called the mechanical equivalent of heat. To establish these statements Mr. Tyndall performs many experiments. He drops a leaden ball from the top of the lecture room; measures the heat generated in the descent and concussion. Fires a rifle bullet at a target; measures the heat generated by the known velocity. "But a rifle bullet, if formed of lead, moving at a velocity of 223 feet in a second, would generate, on striking a target, an amount of heat which, if concentrated in the bullet, would raise *its* temperature 30°; with six times this velocity it will generate thirty-six times this amount of heat. Hence, 36 times 30, or 1,080°, would represent the augmentation of temperature of a rifle ball on striking a target with a velocity of 1,338 feet a second. This is more than sufficient motion to fuse the lead." From these and other considerations he concludes that it is manifest that if we know the *velocity* and *weight* of *any projectile* we can calculate with ease the amount of heat developed by the destruction of its moving force." For example: "Knowing as we do the weight of the earth and the velocity with which it moves through space, a simple calculation would enable us to determine the exact amount of heat which would be developed, supposing the earth to be stopped in her orbit." Meyer and Helmholtz have made this calculation, and found that the quantity of heat generated by this colossal shock would be quite sufficient not only to fuse the entire earth, but to reduce it in great part to vapor." "Thus," says Mr. Tyndall, "by the simple stoppage of the earth in its orbit, the elements might be caused to 'melt with fervent heat.' The amount of heat thus developed would be equal to that derived from the combustion of fourteen globes of coal, each equal to the earth in magnitude. And if, after the stoppage of its motion, the earth should fall into the sun, as it assuredly would, the amount of heat generated by the blow would be equal to that developed by the combustion of 5,000 worlds of solid carbon."

Heat can produce mechanical force, and mechanical force can produce heat. Some common quality must therefore unite this agent and the ordinary forms of mechanical power. This is proved to be motion.

There are two theories of heat—the material and the dynamical