the blood of vertebral animals, careful investigations into the structure of the ductless glands, and several experiments, he deduced the following conclusions :—

1. That the blood corpuscles of vertebrate animals are originally formed in the lymphatic glandular system, and that the great majority of them on joining the circulation, become coloured in a manner that is as yet unexplained. Hence, the blood may be considered as a secretion from the lymphatic glands, although in the higher animals that secretion only becomes fully formed after it has received colour by exposure to oxygen in the lungs.

2. That in the mammalia, the lymphatic glandular system is composed of the spleen, thymus, thyroid, supra-renal, pituitary, pineal, and lymphatic glands.

3. That in fishes, reptiles, and birds, the coloured blood corpuscles are nucleated cells originating in these glands, but that in mammals, they are free nuclei, sometimes derived as such from the glands, at others, developed within colourless cells.

4. That in certain hypertrophies of the lymphatic glands, their cell elements are proportionally increased in number, and under such circumstances the colourless cells of the blood are also proportionally increased. This is Leucocythemia.

5. That the solution of the corpuscles of the blood, conjoined with the effete matter derived from the tissues, which is not converted into albumen, constitute blood fibrin.

2. On the Mechanical action of Radiant Heat or Light : On the Power of Animated Creatures over Matter : On the Sources available to Man for the production of Mechanical Effect. By Professor William Thomson.

On the Mechanical Action of Radiant Heat or Light.

It is assumed in this communication that the undulatory theory of radiant heat and light, according to which light is merely radiant heat, of which the vibrations are performed in periods between certain limits of duration, is true. “ The chemical rays,” beyond the violet end of the spectrum, consist of undulations of which the full vibrations are executed in periods shorter than those of the extreme visible violet light, or than about the eight hundred million millionth

of a second. The periods of the vibrations of visible light lie between this limit and another, about double as great, corresponding to the extreme visible red light. The vibrations of the obscure radiant heat beyond the red end are executed in longer periods than this; the longest which has yet been experimentally tested being about the eighty million millionth of a second.

The elevation of temperature produced in a body by the incidence of radiant heat upon it is a mechanical effect of the dynamical kind, since the communication of heat to a body is merely the excitation or the augmentation of certain motions among its particles. According to Pouillet's estimate of heat radiated from the sun in any time, and Joule's mechanical equivalent of a thermal unit, it appears that the mechanical value of the solar heat incident perpendicularly on a square foot above the earth's atmosphere is about eighty-four foot-pounds per second.

Mechanical effect of the statical kind might be produced from the solar radiant heat, by using it as the source of heat in a thermodynamic engine. It is estimated that about 556 foot-pounds per second of ordinary mechanical effect, or about the work of "one horse power," might possibly be produced by such an engine exposing 1800 square feet to receive solar heat, during a warm summer day in this country; but the dimensions of the moveable parts of the engine would necessarily be so great as to occasion practical difficulties in the way of using it with economical advantage that might be insurmountable.

The *chemical* effects of light belong to the class of mechanical effects of the statical kind; and reasoning analogous to that introduced and experimentally verified in the case of electrolysis by Joule, leads to the conclusion that when such effects are produced there will be a loss of heating effect in the radiant heat or light which is absorbed by the body acted on, to an extent thermally equivalent to the mechanical value of the work done against forces of chemical affinity.

The deoxidation of carbon and hydrogen from carbonic acid and water, effected by the action of solar light on the green parts of plants, is (as the author recently found was pointed out by Helmholtz* in 1847), a mechanical effect of radiant heat. In virtue of this action

* "Ueber die Erhaltung der Kraft, von Dr H. Helmholtz." Berlin, 1847.

combustible substances are produced by plants; and its mechanical value is to be estimated by determining the heat evolved by burning them, and multiplying by the mechanical equivalent of the thermal unit. Taking, from Liebig's *Agricultural Chemistry*, the estimate 2600 pounds of dry fir wood for the annual produce of one Hessian acre, or 26,910 square feet, of forest land, (which in mechanical value appears not to differ much from estimates given in the same treatise for produce of various kinds obtained from *cultivated* land,) and assuming, as a very rough estimate, 4000 thermal units centigrade as the heat of combustion of unity of mass of dry fir wood; the author finds 550,000 foot-pounds (or the work of a horse-power, for 1000 seconds), as the mechanical value of the mean annual produce of a square foot of the land. Taking $50^{\circ} 34'$ (that of Giessen,) as the latitude of the locality, the author estimates the mechanical value of the solar heat which, were none of it absorbed by the atmosphere, would fall annually on each square foot of the land, at 530,000,000 foot-pounds; and infers that probably a good deal more, $\frac{1}{1000}$ of the solar heat, which actually falls on growing plants, is converted into mechanical effect.

When the vibrations of light thus act during the growth of plants, to separate, against forces of chemical affinity, combustible materials from oxygen, they must lose *vis viva* to an extent equivalent to the statical mechanical effect thus produced; and therefore quantities of solar heat are actually put out of existence by the growth of plants, but an equivalent of statical mechanical effect is stored up in the organic products, and may be reproduced as heat, by burning them. All the heat of fires, obtained by burning wood grown from year to year, is in fact solar heat reproduced.

The actual convertibility of radiant heat into statical mechanical effect, by inanimate material agency, is considered in this paper as subject to Carnot's principle; and a possible connection of this principle with the circumstances regarding the quality of the radiant heat (or the colour of the light), required to produce the growth of plants, is suggested.

On the Power of Animated Creatures over Matter.

The question, "Can animated creatures set matter in motion in virtue of an inherent power of producing mechanical effect?" must be answered in the negative, according to the well-established theory

of animal heat and motion, which ascribes them to the chemical action (principally *oxidation*, or a combustion at low temperatures), experienced by the food. A principal object of the present communication is to point out the relation of this theory to the dynamical theory of heat. It is remarked, in the first place, that both animal heat and weights raised or resistance overcome, are *mechanical* effects of the chemical forces which act during the combination of food with oxygen. The former is a dynamical mechanical effect, being thermal motions excited; the latter is a mechanical effect of the statical kind. The whole mechanical value of these effects, which are produced by means of the animal mechanism in any time, must be equal to the mechanical value of the work done by the chemical forces. Hence, when an animal is going up-hill or working against resisting force, there is less heat generated than the amount due to the oxidation of the food, by the thermal equivalent of the mechanical effect produced. From an estimate made by Mr Joule, it appears that from $\frac{1}{4}$ to $\frac{1}{6}$ of the mechanical equivalent of the complete oxidation of all the food consumed by a horse may be produced, from day to day, as weights raised. The oxidation of the whole food consumed being, in reality, far from complete, it follows that a less proportion than $\frac{5}{6}$, perhaps even less than $\frac{3}{4}$, of the heat due to the whole chemical action that actually goes on in the body of the animal, is given out as heat. An estimate, according to the same principle, upon very imperfect data, however, is made by the author, regarding the relation between the thermal and the nonthermal mechanical effects produced by a man at work; by which it appears that probably as much as $\frac{1}{6}$ of the whole work of the chemical forces arising from the oxidation of his food during the 24 hours, may be directed to raising his own weight, by a man walking up-hill for 8 hours a-day; and perhaps even as much as $\frac{1}{4}$ of the work of the chemical forces, may be directed to the overcoming of external resistances by a man exerting himself for 6 hours a-day in such operations as pumping. In the former case there would be not more than $\frac{5}{6}$, and in the latter not more than $\frac{3}{4}$ of the thermal equivalent of the chemical action emitted as animal heat, on the whole, during the 24 hours, and the quantities of heat emitted during the times of working would bear much smaller proportions respectively than these, to the thermal equivalents of the chemical forces actually operating during those times.

A curious inference is pointed out, that an animal would be sensibly less warm in going up-hill than in going down-hill, were the breathing not greater in the former case than in the latter.

The application of Carnot's principle, and of Joule's discoveries regarding the heat of electrolysis and the calorific effects of magneto-electricity, is pointed out; according to which it appears nearly certain that, when an animal works against resisting force, there is not a *conversion of heat into external mechanical effect*, but the full thermal equivalent of the chemical forces is *never produced*; in other words that the animal body does not act as a *thermo-dynamic engine*; and very probable that the chemical forces produce the external mechanical effects through electrical means.

Certainty regarding the means in the animal body by which external mechanical effects are produced from chemical forces acting internally, cannot be arrived at without more experiment and observation than has yet been applied; but the relation of mechanical equivalence, between the work done by the chemical forces, and the final mechanical effects produced, whether solely heat, or partly heat and partly resistance overcome, may be asserted with confidence. Whatever be the nature of these means, consciousness teaches every individual that they are, to some extent, subject to the direction of his will. It appears, therefore, that animated creatures have the power of immediately applying, to certain moving particles of matter within their bodies, forces by which the motions of these particles are directed to produce desired mechanical effects.

*On the Sources available to Man for the Production of
Mechanical Effect.*

Men can obtain mechanical effect for their own purposes either by working mechanically themselves, and directing other animals to work for them, or by using natural heat, the gravitation of descending solid masses, the natural motions of water and air, and the heat, or galvanic currents, or other mechanical effects produced by chemical combination, but in no other way at present known. Hence the stores from which mechanical effect may be drawn by man belong to one or other of the following classes:—

- I. The food of animals.
- II. Natural heat.

III. Solid matter found in elevated positions.

IV. The natural motions of water and air.

V. Natural combustibles (as wood, coal, coal-gas, oils, marsh gas, diamond, native sulphur, native metals, meteoric iron.)

VI. Artificial combustibles (as smelted or electrolytically-deposited metals, hydrogen, phosphorus.)

In the present communication, known facts in natural history and physical science, with reference to the sources from which these stores have derived their mechanical energies, are adduced to establish the following general conclusions:—

1. *Heat radiated from the sun* (sunlight being included in this term) *is the principal source of mechanical effect available to man.** From it is derived the whole mechanical effect obtained by means of animals working, water-wheels worked by rivers, steam-engines, and galvanic engines, and part at least of the mechanical effect obtained by means of windmills and the sails of ships not driven by the trade-winds.

2. The motions of the earth, moon, and sun, and their mutual attractions, constitute an important source of available mechanical effect. From them all, but chiefly, no doubt, from the earth's motion of rotation, is derived the mechanical effect of water-wheels driven by the tides. The mechanical effect so largely used in the sailing of ships by the trade-winds is derived partly, perhaps principally, from the earth's motion of rotation, and partly from solar heat.

3. The other known sources of mechanical effect available to man are either terrestrial—that is, belonging to the earth, and available without the influence of any external body,—or meteoric,—that is, belonging to bodies deposited on the earth from external space. Terrestrial sources, including mountain quarries and mines, the heat of hot springs, and the combustion of native sulphur, perhaps also the combustion of all inorganic native combustibles, are actually used, but the mechanical effect obtained from them is very inconsiderable, compared with that which is obtained from sources belonging to the two classes mentioned above. Meteoric sources, including only the heat of newly-fallen meteoric bodies, and the combustion of meteoric iron, need not be reckoned among those available to man for practical purposes.

* A general conclusion equivalent to this was published by Sir John Herschel in 1833.—See his *Astronomy*, edit. 1849. § (399.)

The following Gentleman was duly elected an Ordinary Fellow :—

Dr JOHN WYLIE, late Physician-General, Madras.

The following Donations to the Library were announced :—

Smithsonian Contributions to Knowledge. Vol. II. Collection of Various Reports. 4to.—*From the Smithsonian Society.*
 Transactions of the Zoological Society of London. Vol. IV., Pt. 1. 4to.
 Proceedings of the Zoological Society of London. Nos. 201–213. 8vo.
 Proceedings of the American Association for the Advancement of Science. August 1850. 8vo.—*From the Association.*
 Transactions of the Horticultural Society of London. 2d Series. Vol. II., Pts. 3, 4, 5, 6; Vol. III., Pts. 1, 2, 3. *From the Society.*
 Novi Commentarii Academiæ Scientiarum Instituti Bononensis. Tom. VI., VII., VIII., IX., X. 4to.—*From the Academy.*
 Memorie della Accademia delle Scienze dell' Istituto di Bologna. Tomo I. 4to.—*From the Academy.*

Monday, 16th February 1852.

MR RUSSEL in the Chair.

The following Communications were read :—

1. On some improvements in the instruments of Nautical Astronomy. By Professor C. Piazzzi Smyth.

The excessive motion of a ship at sea renders the use of the ordinary instruments employed on land impossible, and restricts the sailors to the use of one on the principle of the duplication of images discovered by Hadly.

The favourite form is at present, and has always been, that of a quadrant or sextant, *i.e.*, a part of a circle, rather than a whole one, though this has often been brought forward by scientific men, and proved to be the most accurate : but the construction of these circles was generally too complicated, and practically unsuited to the circumstances usually met with at sea.

Taking the best of the sextants, then, as the form generally found in actual use, the author shewed that it laboured under many disad-