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A STUDY IN BIOKINETICS

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I. IS THERE A STANDARD UNIT OF MEASURE FOR PHYSIOLOGICAL ACTIVITIES?

No biologist will deny probably that the conceptions of the cell and gene as biological units have been of great value in the understanding of development, growth and heredity of living things. These concepts are doubtless as fundamental and indispensable to the morphologist as the concepts of molecule and atom are to the chemist. However, in the field of physiology, the aim of which is function rather than form, one seeks in vain for a unit of similar significance. The reason for this lies partly in the lack of control, and, if not in control, in the statement of experimental conditions.

For example, if one wishes to gather from the literature on heart metabolism the determinations of carbohydrate and oxygen consumption and to reduce them to a common basis for comparison, one finds the task almost hopeless. For some one or another important condition or factor of the experiment has usually been omitted in the report. The results may be given in grams or cc per unit of time, but the rate of beat, or the maximum tension exerted, or the weight of the contracting mass, or the temperature has not been definitely stated. How then is one to compare the metabolism of one heart with that of another, to say nothing of a comparison of the metabolism of heart muscle in general with that of skeletal and smooth muscle? If a number of reliable observations, say, on the carbohydrate and oxygen consumption of the various kinds of muscle could be reduced with certainty to the weight of these substances used up per gram of muscle, per gram tension exerted, per single contraction, one would begin to feel that one had the materials for a search for a common standard of measure of muscle activity, and indeed a promise of finding a common standard of measure for all vital activities; the point being that a smallest unit of vital activity first must be recognized and agreed upon, and second that the observed metabolic changes are reducible to that unit. On such a basis the possibility can not be excluded that ultimately physiologists may find a reliable yardstick for the final comparison of any one with any other elemental physiological process—a unit of measure that will serve finally even in the analysis of the more complicated mechanisms.

It should be noted at the outset that this unit is no philosopher's concept of an *élan vital,* or an *entelechie* —of a vague but indispensable essence of *bios.* On the contrary, it must express definitely the energy of the smallest activity that can be recognized and agreed upon as physiological, as peculiarly living, as opposed to the activity of non-living matter.

If such a standard does not exist or defies analysis and definition it would seem that we shall be obliged to abandon for all time any hope of carrying our analysis and description of the physiology of living matter much beyond the point where we have now arrived.

Modern physiologists thus far have been quite content, and rightly so, whenever they have been able, to take the measure of a living process in terms of the units set up as standard by the physicist and chemist. For the most diverse phenomena of the non-living world have been brought together under increasingly inclusive concepts and thus have been expressed in more comprehensive units of measure. Indeed it is a striking fact that the physicist and chemist have been able to arrive at their most far-reaching generalizations only in so far as they have been able to marshal their specific measurements under broader and more inclusive standards of measure. In his preliminary study, therefore, the physiologist perhaps can do nothing better than to inquire as to how far he is able to marshal the diverse and special measurements of various living processes similarly under broader and more inclusive standards. And if these more inclusive standards turn out to be also merely the standards set up by the physicist, he still may feel justified in having made the attempt and in believing that the goal of standard unit of physiological activity has been brought thereby somewhat nearer to realization. Accordingly what follows in the present paper consists of a preliminary examination of the field to that end.

II. ON THE NATURE OF EXCITATION

All physiology may be defined simply as a study of stimulation and response of living matter. But stimulation is the process of arousing a state of excitation at a given point, and since all response is preceded and accompanied by physiological excitation our definition may be simplified further by saying that all physiology is a study of the excitation of living matter. Is there any property or process common to all the manifold forms of excitation, of conduction and response, that physiologists thus far have studied? The answer to this question is decidedly yes. For in every case where the tissue can be tested by appropriate experiment the excitation aroused by a stimulus has been found to be accompanied by an electrical disturbance, long known as the "action current," more lately referred to as the "action potential" both phrases leaving the word "electrical" to be inferred. This is true not only for the immediate region of excitation, the receptor or sense organ, but for the conducted wave of excitation be it along a nerve fiber or over a muscular organ, or any other excitable tissue. Just recently this electric change has been observed for single muscle and nerve fibers and finally for a single sensory-end point such as the so-called muscle spindle. There can be no doubt that it will be demonstrated finally for such excitations as the contraction of the vorticella stalk and of a single flagellum of the flagellates.

The newer physics teaches us that the setting up of a difference of electrical potential is due to the pressure of negatively charged particles called electrons; that the electrical current is a transfer, or a flow of these electrons in one direction and that the free electrons move with great speed in an oscillatory or vibrational manner.

Excitation of living matter therefore must be at bottom a tearing loose and transfer of electrons. How is it possible for the many varied forms of stimulation (which we know are able to excite living matter) to excite electrons? For the answer we must examine the various forms of external stimuli themselves. When this is done it is found that they also are vibrational in character, molar, that is made up of molecular vibrations in the case of mechanical, sonic and auditory stimuli, and thermal stimuli when these are due to conducted heat. In the case of electricity and radiated heat, in short, in case of all forms of radiant energy that serve as adequate stimuli to living matter, these all are obviously vibrational in character. These widely different forms vary in wave-length from nearly two meters to a fraction of a mm (as in the case of mechanical and sound stimulations) to the exceedingly short wave-length of the visible, ultra-violet and Roentgen rays. How can stimuli of such various wave-lengths set up electron transfers?

Before answering this question it is worth while noting that, so far as we know, living matter is not stimulated by radiant energy of all wave-lengths; for example, the Hertzian, or "radio" waves, the electromagnetic waves and the shortest of all known, the cosmic rays, produce no stimulation. It will be noted that some of these non-stimulating waves have longer, some shorter, wave-lengths than, say, the visible which probably affect all forms of life. In other words, there are not only islands of deafness in certain ears but in all living matter there are islands of irresponsiveness to certain groups (or octaves) of the great keyboard of vibrational energy.

The explanation of this is given with the answer as to why living matter is excited at all by any vibrational energy. Clearly this must be because living matter contains resonators or "detectors" that "synchronize" with certain wave-lengths and thus excite electrons in the living body. Hence we have the "action currents," the "action potential" in the living body accompanying all forms of excitation, that is all forms of effective stimulus and response.

An effective and adequate stimulus, therefore, must be vibrational in character. But before leaving this definition it should be pointed out that one other characteristic is also a *sine qua non.* There must be a certain suddenness in the change, a certain minimal rate of change, in the intensity of the external stimulus. This explains further, perhaps, why living matter is insensible to certain forms of radiant energy mentioned above. We can move from the dark into the light but when do we ever move out of or into the terrestrial field of magnetism? These magnetic waves are all-pervasive and their rates of change in intensity are of the slowest. The cosmic rays likewise are always with us at the same intensity so far as we know. Living matter has had no occasion to develop appropriate resonators to detect them and would have no use for them if it did.

All living matter is at times irritable, and sensory end-organs are only masses of living matter specially organized in different ways to exhibit extreme degrees of irritability, that is, to play the rôle of resonators to changes in intensity of various forms of vibrational energy.

We now then begin to perceive what some of the conditions of a living tissue must be when in a state of irritability. Irritability requires a difference of electrical potential set up between the two sides of an interface in such a state of equilibrium of surface forces as to be vulnerable to a sudden change of certain vibrational intensities. When this latter effects an electron transfer, then an adequate stimulus results, the action potential is observed, the excited state is set up, in some cases propagated, and finally motor end-organs are likewise excited.

From what has been said in the foregoing section it no longer appears unreasonable that, at least in some of the physiological processes, we are dealing with radiational forms of energy and electron transfers. If this is the case then the question becomes pertinent: Do any of the laws of radiation, as developed by the modern physics, hold in the case of such physiological activities? Before answering this question it is in order first to make a brief statement of such laws and equations as will be made use of in the answer.

III. LAWS OF RADIATION AND BIOLOGICAL PROCESSES

The law of equivalence as formulated by Einstein states that for every molecule or atom undergoing change in photochemical reaction one quantum of radiant energy, hν, is absorbed. If q′ represents the total absorbed light energy in terms of ergs, and N the total number of molecules or atoms engaged in the reaction then

$$(1) \qquad q' = Nh\nu, \text{ ergs; whence } q'/Nh\nu = 1.$$

This equation has been verified for certain photochemical reactions. For certain other photochemical reactions, where the equation does not appear to hold directly, reasons have been given to show that the observations dealt not with the primary photochemical reaction but with "secondary" and even "chain" reactions; indeed in several of the exceptional cases, in which the primary action was finally found, the law of equivalence was also found to hold. At the present time it is said the law of equivalence has been found to hold for some 28 photochemical reactions; there are a number in which the primary action has not yet been discovered.

Stark in 1908 first gave evidence that such a law existed for photochemical reactions and Einstein, of relativity fame, put the equation on a firm theoretical basis (1912). The physicist, E. Warburg, (1912–14) gave the first complete experimental proofs that the law holds, work that was promptly followed by numerous other confirmatory experiments during the score of years that now have intervened. The physical-chemists were interested from the beginning; and to some of them, notably Bodenstein, Trautz (1904–1918), Haber, C. M. Lewis and Perrin (1919), among others, it occurred that if photochemical reactions are a function of the frequency of the effective visible and ultra-violet wave-lengths then it may be that thermochemical reactions are likewise a function of the frequency of the respective wave-lengths that lie in the infra-red portion of the spectrum.

The equations expressing the relation between temperatures, heat of activation and velocity of reaction for ordinary chemical processes, that go on independently of light, had been determined long before; but now it was advocated, for instance, that an equation expressing the relations in a thermochemical reaction based upon the laws of radiation was nothing more or less than that of the well-known equation expressing the velocity of a reaction as influenced by temperature. Thus it was pointed out by M. Trautz and by J. Perrin that the equation

$$\ln K = \frac{h\nu}{k}\left(\frac{T_1}{1} - \frac{T_2}{1}\right) \tag{2}$$

(in which K is the velocity of the reaction; ν, the frequency of the effective wave-length; k and h, radiation constants; T_1 and T_2, temperature in degrees absolute) is practically nothing more or less than the van't Hoff equation,

$$\ln K = \frac{q}{2}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \tag{3}$$

in which q in terms of calories of heat (instead of $h\nu$ in terms of ergs) is the critical increment of energy required per gram-molecule of the chemical substance activated.

Now this q factor of equation (3) has been a subject of study for a number of years by both chemists and physiologists, for obviously it can be determined if one only observes the velocities of the reaction (k) at different temperatures. The physiologist reasons that if q represents the amount of energy required per gram-molecule of substance undergoing chemical change in a purely chemical reaction, then likewise q determined from the observed velocities of certain biological processes at different temperatures will also represent the required energy per gram-molecule undergoing chemical change in the living body, even though just what the chemical change is, may not be known.

Do the q′ and q terms of the two equations, (1) and (3), stand essentially for one and the same thing? Are they equal and interchangeable? Theoretically in (1) q′ is the total increment of energy required for activation of a gram-molecule of substance undergoing photo-chemical reaction while in (3) q is the total increment in energy required for activation of a gram-molecule of substance in a thermochemical reaction. Is the energy here involved in the form of radiant heat or of conducted heat? Increase of temperature involves an increase in the speed of motion of the molecules of the body heated, causing increased number of molecular impacts and bombardments. Arrhenius considered this but could not find enough energy from this effect to account for the enormous influence that a rise of temperature has upon the velocity of reaction and rejected it as an inadequate explanation of the phenomenon.[2a] This forces one to turn to the radiant aspect of the heat for an explanation.

The champions of the radiational hypothesis of thermal-chemical activation, therefore, believed themselves justified in assuming that the jump in the frequencies from the lower to the higher temperatures represents a critical increment of energy in the sense of that phrase as used by the exponents of the radiational theory of photochemical reactions, and that actual electron-transfers thus are effected in the thermal as well as in the photochemical reactions. If so, then q′ and q of equations (1) and (3), if not equal, can be made so by introducing a correcting factor, as Perrin, among others, did and as appears in the constant of equation (2).

According to Wien's law of displacement, wavelength and therefore frequency of radiant energy, is a function of the temperature and expressed by the equation,

$$\lambda\mu T = b \tag{4}$$

But, $c/\lambda\mu = \nu$, and therefore the law of equivalence as expressed in equation (1) may be put as

$$q' = NhCT/b, \text{ where} \tag{5}$$

N is Loschmit's number, or the Avogadro number, $= 6.06 \cdot 10^{23}$
h is Planck's radiational constant, $= 6.55 \cdot 10^{-27}$,
C is the speed of light in μ, $= 3 \cdot 10^{14}$, and
b is the constant in Wien's law, $= 2882$.

When the constants in (5) are put in a single figure, we have

$$q' = 41.2 \cdot 10^{7} \cdot T \text{ ergs.} \tag{6}$$

For those chemical reactions and for those physiological processes, that are influenced by temperature in their rates of reaction, it has become customary to reduce the observed results of observations to a common standard, that is, to a temperature coefficient for differences of ten degrees, expressed with the symbol, Q_{10}. If Q_{10} is known for a given process the determination of q is simplified. For, from equation (3) it follows that in the special cases where the velocities of reaction are k_2 and k_1 at temperatures T_1 and T_2, when the latter are 10 degrees apart, $k_2/k_1 = Q_{10}$. Then, introducing the necessary modulus to convert natural into Briggsian logarithms and also the factor $4.19 \cdot 10^7$ to convert calories into ergs, equation (3) becomes

$$q = \log Q_{10} \cdot 4.57 \cdot \frac{T\,(T+10)}{10} \cdot 4.19 \cdot 10^{7} \text{ ergs.}$$

By taking a temperature that is median to T and T + 10 (say, Tm) we have an approximation equation out of (3) where

$$q = 1.915 \cdot 10^{7} \cdot \log Q_{10} \cdot T^{2}_{m} \text{ ergs.} \tag{7}$$

But Q_{10} varies between 2 and 3 for the most part. If we put $Q_{10} = 2.5$, then equation (7) takes the special and simple form of

$$q = 0.761 \cdot 10^{7} \cdot T^{2} \text{ ergs.} \tag{8}$$

[2a] But see also the papers of K. F. Herzfeld, *Ann. der Physik.*, 1919, vol. 59, p. 635, and *Zeitschr. f. Physik.*, 1922, vol. 8, p. 132.

The Einstein photochemical equation in the form of (6) may now be compared easily with the van't Hoff-Arrhenius thermodynamical equation in the form of (8).

Physiological reactions among the cold blooded animals proceed mostly between 5 and 25 degrees C, and in this range, even for one and the same reaction, Q_{10} may vary from 3 to 2. Below I have tabulated the values of q in terms of 10^{11} ergs as calculated from the photochemical equation (6) and also from the thermodynamical equation (7). In both cases the calculation is made for the median temperatures, at which the corresponding values of Q_{10} are sometimes found, and on the assumption that a purely radiational effect could be had at the infra-red frequencies represented by the given temperatures. In the last column the ratio of q/q′ is given for each of the temperatures; from definition this is also the value of q/Nhv.

TABLE 1

T_m, degrees absolute	Q_{10}	Energy in terms of ergs/10^{11}		$\frac{q}{q'}$
		q	q′	
283	3.0	10.66	1.164	10.94
288	2.5	6.31	1.186	5.33
293	2.0	4.69	1.206	3.85
303	1.0	0	1.249	0

It is quite obvious thus that in this range of temperature q in the thermodynamic equation varies greatly, that is, roughly as the square, or as the logarithm, of the temperature coefficient (when this latter varies); whereas q′, as determined from the photochemical equation, varies just linear with the temperature. The table finally shows that, when $Q_{10}=1$, then $q=0$; whereas q′ is still in quite linear proportion to T. This simply emphasizes the point that in purely photochemical reactions a rise of temperature (in the sense of heat conducted to the system, which latter thereby becomes a warmer body) has no effect whatever on the reaction.

When biologists began to point out that those physiological processes having a temperature coefficient lying between 2 and 3 were probably processes primarily dependent upon chemical reactions, the objection was raised that such was not necessarily the case because some (photochemical) reactions have their $Q_{10}=1$. This argument led these critics into the fallacy of implying that, because some chemical reactions are not influenced in their rates by temperatures, those reactions that are so influenced can not be chemical reactions!

But let us take a case where the temperature coefficient is nearly constant throughout the range of temperature employed in the foregoing table, say $Q_{10}=2.5$. Putting q and q′ again in terms of ergs/10^{11} we see that the q values vary with the temperature in the same linear fashion, as do the q′ values.

TABLE 2

T_m	q	q′	q/q′
278	5.88	1.144	5.14
283	6.06	1.164	5.21
288	6.31	1.186	5.33
293	6.54	1.206	5.42

In table 1, last column, one sees that the ratio q/q′ also tends to be constant.

This ratio shows that when $Q_{10}=2.5$ the energy involved in the thermodynamic equation is some five times greater than that involved in the radiational equation. Does this mean that in the former reaction there are some five quanta of the infra-red radiations absorbed per molecule that undergoes chemical transformation? Or does it mean that the chemical reaction can be accelerated merely by the increase in the rate of molecular impacts? In this latter case, then, it takes five times the energy when applied in the form of molecular impacts to do what is accomplished when the energy required is all in the form of radiant energy. There is still the possibility that a combination of both forms of energy is involved when $Q_{10}>1$, where q′ parts of q are supplied by radiations (increase in electronic frequencies) and $q-q'$ of the energy is supplied by molecular impacts. This brings the discussion to a point where a physiologist can not carry it further to any advantage and where the interested reader would more profitably consult such works as the reports of the Symposia on Radiation,[1] and Tolman,[2] where one also will find references to the literature. Brief review and fuller citation of the literature by the writer,[3] will also be found in a recent article of which this paper is a brief summary and continuation. Let us rather turn our attention to a few specific cases of physiological processes.

IV. ANALYSIS OF PHYSIOLOGICAL PROCESSES

The phenomenon of photosynthesis in green plants is one that involves the problem stated above and

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[1] See *Chemical Reviews*, 1928, vol. v, p. 39; and 1930, vol. vii, pp. 203–258.

[2] R. C. Tolman, "Statistical Mechanics with Applications to Physics and Chemistry," N. Y., 1927, pp. 276–285.

[3] C. D. Snyder, "Quantitative Relations in Biological Processes and the Radiation Hypothesis of Chemical Activation," *Quar. Rev. of Biology*, 1931, Sept. number [in press].

probably the studies of O. Warburg[4] and of O. Warburg and Negelein[5] will be most useful as illustration. In these studies the amounts of carbonic acid assimilated by the action of light on a suspension of the one-celled alga, *Chlorella,* were observed. The light used was of certain selected wave-lengths whose intensities as well as the amounts absorbed by the cells were measured. In the later work the results lead the authors to conclude that photosynthesis in *Chlorella* does not follow directly the law of equivalence, for not one quantum but from 4 to 5 quanta of light energy were found to be absorbed per molecule of carbonic acid assimilated, about 4 quanta for red or yellow light, 5 quanta for blue light.

In the earlier work Warburg reinvestigated what is known as the "Blackman reaction" which refers to the Blackman's observations that the rate of photosynthesis at the higher of the ordinary light intensities is influenced by temperature somewhat to the same extent as are the usual chemical reactions, with temperature coefficients greater than 2; at the least effective intensities of light, however, Q_{10} approaches unity as is the case with many photochemical reactions *in vitro.*

Now it is just this Blackman reaction that illustrates a case where both thermal and photochemical reactions are known to be combined in a living process, and a survey of the results of Warburg are of the greatest interest. In table 3 the present writer has added certain quantities to Warburg's results (which are there reproduced) that can be calculated on the basis of the equations given in part I of this paper, namely the q value from the temperature coefficients, *i.e.,* the "heat of activation," according to the thermodynamic equation (7) but in terms of calories; and finally the ratio of the value of q to the (theoretical) radiant thermal energy per gram molecule of carbonic acid assimilated at the several mean temperatures, and as calculated in calories according to equations (1) and (6)—in short the q/q′ or q/Nhν ratios.

TABLE 3

The Heat of Activation in Terms of Quanta for Photosynthesis in Chlorella. After the Data of O. Warburg

Temp. range, deg. C.	5–10	16–25	5.4–10	10–20	20–30	15–25	25–32
Rel. intensity of light	16	16	45	45	45	1.8	1.0
Q_{10}	4.8	2.0	4.3	2.1	1.6	1.06	1.00
q = heat in cal./1000	24.50	11.57	22.70	12.40	8.26	1.11	0
q/Nhν = quanta per molecule CO_2	8.8	4.0	8.2	4.36	2.88	0.384	0

From this table it may be seen at once that for weakest effective intensities of light (I = 1.0) the value of Q_{10} is unity; that is, a rise of temperature from 25° to 32° has no effect on the reaction; q, and accordingly q/Nhν, that is the thermal quanta yield becomes zero. But for the higher intensities Q_{10} increases until it becomes more than 4 for the low temperature ranges and is about 2 for the more usual temperature ranges experienced normally by the active cells. "Heats of activation" thus appear and when put in terms of thermal quanta vary from 2.88 to 8.0 per molecule of CO_2 assimilated. But it is to be recalled that from 4 to 5 quanta of light energy also are absorbed independently of the temperature, in which case it further appears that when the greater intensities of the light are employed and at different temperatures, the total of thermal and photo-radiational quanta involved in the synthesis must vary from 7 to 13. It will be noted further that the thermal quanta, for the more moderate temperature ranges and the higher intensities, are 4.0 and 4.36 respectively. This is also about the yield in thermal quanta that can be calculated from the rate of oxygen absorption by green plants in the dark, as observed by Mattheis (1904) and Yabusoe (1924). That is, carbonic acid production (or the reverse process of carbonic acid assimilation) involves about the same number of thermal quanta as the number of light quanta that are involved in carbonic acid assimilation. Further, the quanta yield in all cases lies between 4 and 10 as was shown must be the case (see table 1) for the vast majority of physiological processes influenced by temperature.

The part of the studies on *Chlorella,* however, that seem to be of greater interest, because less complicated, is that where it was shown that independently of temperature, and when the light intensity is low, the quanta yield is 4 to 5 per molecule of carbonic acid assimilated. This yield is striking when compared to the (thermal) quanta yield of those simpler physiological processes that are influenced in their rates by temperature but not at all by light.

The transmission of nervous excitation is such a process. Dealt with statistically, as was done in the former paper previously referred to on this subject,[3] the temperature coefficients for the more moderate range of temperature vary between 1.90 and 2.38 for frogs' motor nerve. These values give quanta yields,

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[4] O. Warburg, *Über die Geschwindigkeit der photochemischen Kohlensäurezerersetzung in lebenden Zellen. Biochem. Zeitschr.* 1919, vol. 100, p. 230.

[5] Warburg und Negelein, *Über die Energieumsatz bei der Kohlensäureassimilation. Zeitschr. f. physikal. Chemie.,* 1922, vol. 106, p. 191.

varying from 3.97 to 5.18 per molecule of whatever substance may be responsible for the transmission of excitation in nerve. In other words, the number of quanta is about the same for a relatively simple physiological process influenced only by heat as it is for an equally simple physiological process that is influenced only by visible light radiations; that is, for carbonic acid assimilation by the green plant when the intensity of the incident rays is weak.

Putting these facts together it seems that the cogency of the problem set forth is established and that there can be no escape from the surmise that the frequency of dark-field radiations in a purely thermal process may play the same rôle that the frequency of visible radiations plays in a purely photochemical process.

This being the case then it would seem that the surmise could be put to the test of experiment by exposing a system, whose reaction is susceptible to thermal changes, to direct infra-red radiations. This indeed has been done by chemists and from their experiments no clear proof has yet been established that absorbed infra-red radiations affect the rate of chemical reaction.[1] However, it would seem that this does not exclude the possibility that with the discovery and application of new methods, the proof may yet be brought forth.

At the same time there is also the possibility that the application of heat to these "thermal systems" brings about radiation among the molecules themselves, that is, the increased force of molecular impacts may produce perturbation among the outer sphere of electrons of atoms, which leads to electron transfers. The atoms themselves thus become sources of radiation, the processes of emission as well as absorption all occurring within the system itself. That this is possible is suggested by the phenomena of chemiluminescence and bioluminescence whereby the application of a variety of external agents, none of which need be primarily radiant energy, the atoms or molecules within the system are brought to a state where they themselves become the source of visible light. If atoms and molecules can thus be made to emit visible radiations it would seem to be all the more probable that they oftener and more easily can be made to emit radiations of lower frequency, that is, infra-red radiations. But such radiations being invisible will be all the less easily demonstrated. Especially must this be the case where the emitted radiations are also absorbed by the same system. Here the chances of detection by a dark-field radiometer obviously become nil.[6]

V. Summary

In the foregoing pages the writer has attempted to point out first, the importance to physiologists of the discovery and application to their problems of a unit of physiological activity to serve as a universal measure of life processes. Second, a survey of the field of excitation and response points to the probability that electron transfers are involved in every case and, therefore, that such a standard of measure, if ever determined, will probably involve terms of radiational units. Third, a brief statement of some of the laws of radiation that seem to be involved is given, together with a sketch of the radiation hypothesis of chemical thermal reaction. Fourth, an analysis of the data of a few physiological processes is then presented, the results of which strongly suggest the possibility that the influence of temperature upon living processes may be due to dark-field radiations quite as much as the photochemical effects in living processes are due to radiation of visible light.

OBITUARY

MEMORIALS

Under the leadership of Reginald P. Bolton, a committee has been organized to raise a fund of $25,000 to preserve the home of John James Audubon in New York City. It is planned to move the house to a city park to be used as a public museum.

A fund is being collected in the Canal Zone for the purchase of an oil painting of General George Washington Goethals, to be hung in the administration building at Balboa Heights. It will be painted by Brigadier General Chester Harding, retired, a former governor of the Canal Zone, who, since leaving the service, has renewed his portrait studies in Paris.

Nature reports that a fête in honor of Henri Moissan was celebrated on October 4, in the cathedral town of Meaux, situated on the banks of the Marne. The delegates were received on October 3 at the Ministry of Foreign Affairs on the Quai d'Orsay, and on the following morning nearly three hundred were taken by special train to Meaux. The ceremonies included the formal presentation to the Communal College (of which Moissan was a pupil from 1864 until 1870) of a plaque on the wall of the entrance hall, and in the afternoon the unveiling, by Mme. Jean Gerard, of a monument in a small square by the side of the town hall. The monument is in the form of

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[6] For a full presentation of the physical aspects of the topics dealt with in this paper see vol. 23, *Handbuch der Physik*, 1926, edited by Geiger; especially chapters 5, 6 and 7 by Pringsheim, Noddack, and Franck and Jordan, respectively.