CHAPTER II

SOURCES OF RADIANT ENERGY

Radiant energy may originate under widely varying conditions. Warm bodies radiate heat. When the temperature rises very high, the radiation becomes visible. Practically all our sources of illumination, from the oil lamp to the incandescent light are based on this principle. However, visible radiation may also be produced from chemical processes, without great increases in temperature, as in the slow oxidation of phosphorus or in the light of the firefly. Too, when an electric current is set up in a tube containing gas at low pressure, though the temperature remains within a few degrees of the room, the tube will emit light.

In this chapter, a division is made between physical and chemical sources of radiation. Though the chemical sources of radiation are more important because they show us that we may expect radiations in biochemical processes, the physical sources are much better known. The discussion begins therefore with the physical sources of rays, followed by the chemical sources of such rays; in Chapter III, the biological effects will also be first demonstrated with rays of physical origin, and afterwards with those emitted by chemical reactions.

A. PHYSICAL SOURCES

Thermal Radiation: Returning for the moment to the wave theory of light, we remember that the oscillations of an electric charge result in the production of radiant energy. Let us see how this idea may be applied to the various sources of radiation with which we are familiar. There is, first, the fact that all bodies emit at all times radiant energy; they also absorb at all times radiant energy. This radiation is due to the vibrations of the atoms (built of electric charges) of which the body is composed. At ordinary

temperatures, this radiation is of very long wave length. However, the radiation becomes visible when the temperature of the body reaches the neighborhood of 500° C. — witness the dull red color of iron which is being heated. At still higher temperatures, e. g. that of the tungsten filament in an electric bulb, the color of the radiation is changed to nearly white, and in some of the hotter stars to a blue-white color. Radiation which arises as a result of the temperature of a body is known as *black body* or *thermal radiation*. The peculiarity of a thermal radiator is that the distribution of energy among the wavelengths depends not at all upon the atoms or molecules of the body, but solely upon its temperature. Table 9 gives the energy radiated by a tungsten filament at various wave lengths for the two temperatures 2500° and 3000° C. It can be seen from these data that thermal radiators are poor sources of ultraviolet.

Table 9. Spectral Distribution of Thermal Radiation from Tungsten

Wave Length in Å	$E_w(\lambda)$ (watt/cm³)[1]	
	2500° C	3000° C
2000	0.07	8.32
2500	7	315
3000	125	2980
3500	869	13100
4000	3360	35900
4500	8930	73100
5000	18400	122000
5500	31400	176000
6000	47600	230000
6500	65200	276000
7000	82700	315000

Atomic Radiation: Everyone is familiar with the neon signs so frequently used at present for advertising purposes. These are nothing more than discharge tubes filled with neon or a mixture of neon and other gases. They are fitted with metal

[1] $E_w(\lambda)$ is the rate of emission of energy in watts, from 1 cm² of surface, in a direction perpendicular to the surface, per unit solid angle, for 1 cm range of wave lengths.

terminals to which electrical potentials are applied, potentials high enough to cause ionization of the gas atoms in the tube. The atoms lose and regain electrons many times a second with the emission of light each time an electron is regained. Such tubes are known variously as arc, glow and discharge tubes depending upon the pressure of gas within them and the voltage necessary to make them function. The most practical sources of ultraviolet, namely the mercury arc and the hydrogen arc are of this type. Other sources may depend simply upon the ionization of air between two naked terminals, such as the carbon arc or the iron or tungsten spark. The latter two are strong sources of ultraviolet but suffer from the disadvantage that they are not sources of constant intensity. In this type of source the temperature is not necessarily much different from room temperature — it is the electrical energy which causes the ionization of the atoms and the resultant emission of light.

B. CHEMICAL SOURCES

Most of the chemical reactions which proceed spontaneously are exothermic, i. e. they liberate energy. Ordinarily, the energy is emitted in form of heat, as the name "exothermic" implies. Occasionally, however, the reaction causes luminescence, the energy being liberated as visible light. As examples may serve the light produced during the slow oxidation of phosphorus, at the hydrogen-oxygen combination, at the reaction of potassium with water, or at the oxidation of pyrogallic acid. Haber has shown that these are not cases of light produced by heat, but that part of the original energy of reaction is liberated in the form of visible light.

By far more common is the emanation of ultraviolet light. Recent investigations make it appear very probable that all chemical reactions emit part of their energy in the form of short ultraviolet rays. This has been proven for such simple processes as $NaOH+HCl = NaCl+H_2O$, and even for the solution of NaCl in water, i. e. $NaCl = Na^+ + Cl^-$, as will be shown later.

Ordinarily, the radiations are very weak, altogether too weak to be registered by the photographic plate. However, it has been possible to prove their existence by the GEIGER-MÜLLER counter which is essentially an extremely sensitive photoelectric cell (see fig. 21).

In this way, FRANK and RODIONOW (1932) proved that a number of common chemical oxidative reactions produced an ultra-violet radiation which could be demonstrated with a sufficiently sensitive instrument. Table 10 gives their results. It was also observed at this time that in some of the reactions, the emanation is greatly increased in the presence of diffuse day light. This physical proof of light from chemical reactions has been verified by GERLACH (1933) who showed that this radiation appears only from quartz vessels, not from glass containers; therefore, it must be of a wave length shorter than 3500 Å. AUDUBERT and VAN DOORMAL (1933) also measured photo-electrically the emission of ultra-violet light by several inorganic oxidations, by the oxidation of alcohol with chromic acid, and by pyrogallic acid in air. Recently, BARTH (1934) could also prove the existence of ultra-violet emission from proteolysis which is known to give an immeasurably small heat of reaction. In all of 25 experiments but one, the number of photo-electrons was larger when exposed to radiation from proteolysis than without this, and in 7 experiments it was more than 3 times as large as the error.

Table 10. Ultra-violet radiation from chemical reactions

Chemical Reaction	Time Interval	Photon impacts per time interval		Increase in impacts by chemical reaction	
	minutes	exposed	control	absolute	percents
Pyrogallic acid + NaOH + air	10	15 ±1.2	10 ±1.0	5	50
	8	38 ±2.0	26 ±1.8	12	46
$SnCl_2 + HgCl_2$	10	29.5 ±1.7	26 ±1.6	3.5	13
$FeSO_4 + K_2Cr_2O_7$ (diff. light)	6[1])	18 ±1.7	13 ±1.5	5	38
„ „	4[1])	17.5 ±2.1	13 ±1.8	4.5	34
„ „	6[1])	18 ±1.7	12 ±1.4	6	50
„ „	9[1])	36 ±2.0	26.5 ±1.7	9.5	36
$FeSO_4 + K_2Cr_2O_7$ (dark) . .	15	27 ±1.3	17 ±1.0	10	60
„ . .	4[1])	12 ±1.8	11 ±1.7	1	9

[1]) Radiation passed a monochromator, only the rays between 2000 and 2700 Å were measured.

These radiations are so very weak that only the most sensitive counters will detect them. However, living cells under certain physiological conditions react very promptly upon irradiation in the wave length range 1800—2600 Å. In fact, they are so sensitive that it has been possible to use them in place of photographic plates for determining the spectra of such radiations. The organisms most used in these experiments are yeasts the growth rate of which is accelerated by short ultraviolet rays under certain conditions. The biological aspects of this acceleration will be discussed in Chapter IV.

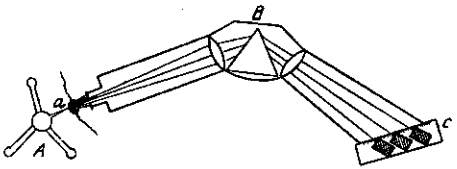

Figure 22. First attempt to obtain a mitogenetic spectrum

a: an electrically excited muscle; *B*: the quartz prism; *C*: agar blocks with yeast on the exposed side, each block receiving rays of known wave length.

The original method consisted simply in placing before the collimator slit of a quartz spectrograph a quartz tube with the reagents to be tested, and to substitute the photographic plate by a succession of tiny blocks of nutrient agar on which yeast in the proper physiological condition was growing. Fig. 22 shows the first attempt, by FRANK (1929) to obtain the spectrum of a frog muscle. Each yeast block was thus exposed to a definite range of the spectrum which could be determined fairly accurately. After irradiation, the yeast was permitted to grow for a short time in order to bring out the growth rate differences, and was then compared with the controls.

By this method, KANNEGIESSER (1931) working with yeast blocks, each representing approximately 50 Å, studied three types of oxidation, namely pyrogallic acid in alkaline solution by air, glucose + $KMnO_4$, and blood serum + H_2O_2. It was found that the growth was stimulated only on the two blocks receiving radiation from 2220—2280 and 2280—2340 Å. None of the other detector blocks differed appreciably from the controls.

From these results, it would appear that all three oxidations have the same spectrum, as far as can be ascertained with this rather crude method.

The next advancement was the division of the spectrum into separate strips of exactly 50 Å each. POTOZKY (1932), by means of glass needles and heavy cellophane, prepared a chamber (fig. 23) the sections of which corresponded exactly to the 50 Å divisions of her spectrograph. By this simple instrument, BRAUNSTEIN and POTOZKY (1932) showed that the spectra of different oxidations possessed certain specific regions besides the general oxidation spectrum. The data of 7 separate experiments are

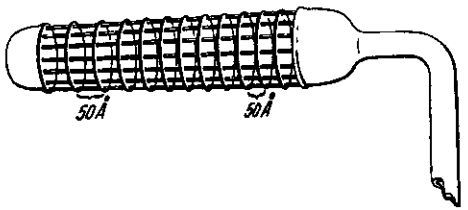

Figure 23. Device for exposing yeast to successive ranges of the spectrum of 50 Å each.

reproduced in Table 11. The various spectra are not quite identical, and even the rather crude determination by 50 Å strips shows differences which remained typically constant when the experiments were repeated. The limit of error is $\pm$ 15.

Table 11. Induction Effects obtained from 50 ÅNGSTROM strips of the Spectra of various Oxidations

Detector: Cell Numbers in liquid Yeast Cultures	1900—1950	1950—2000	2000—2050	2050—2100	2100—2150	2150—2200	2200—2250	2250—2300	2300—2350	2350—2400	2400—2500
$KMnO_4+H_2O_2$	+10	+8	+1	+18	+30	+18	+63	+18	+70	+ 2	+5
$K_2Cr_2O_7+FeSO_4$	+11	+8	+4	+ 2	+30	+23	+68	0	+45	0	+1
$HNO_3+FeSO_4(+H_2SO_4)$	+ 5	—7	+3	+ 5	+ 4	+ 2	+10	+19	+29	+34	—7
$KClO_3+Zn+NaOH$	+ 7	0	0	+ 4	+ 8	+20	+23	+26	+28	— 5	+2
$FeCl_3+NH_2OH \cdot HCl$	+ 5	—2	+3	+ 7	— 9	0	+46	+78	+90	+51	—2
H_2O_2+Pt	+ 6	—3	0	+13	+29	+39	+29	+20	+36	— 8	+1
$HgCl_2+SnCl_2$	+ 4	+6	—2	+ 3	+49	— 4	+60	+58	+97	+36	—4
							Range obtained by KANNEGIESSER				

It was also found that diffuse daylight increases the intensity of some reactions, e. g. of $K_2Cr_2O_7+FeSO_4$, but does not affect the spectrum itself.

A still more detailed analysis was finally accomplished by PONOMAREWA (1931) who used 10 Å sections. It was impossible to divide the agar surface into such narrow strips and there was always the possibility of confusion by the spreading effect (see p. 110). Therefore, PONOMAREWA screened off all radiation except

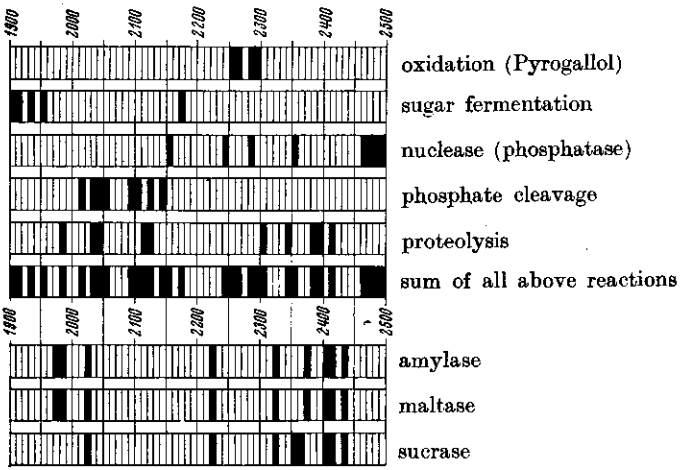

Figure 24. The spectra of some common biological reactions.

one narrow slit of 10 Å. The position of this slit could be changed over the entire spectral range. By this method, only one small part could be studied at one time, and the progress of such analysis is slow. However, if the general spectrum has been investigated by the above-mentioned coarser methods, the negative regions need not be examined, and the amount of work is thus greatly reduced. On account of the very low intensity, this procedure is usually combined with intermittent radiation (see p. 103). In this way, PONOMAREWA could show that the glycolytic spectrum of blood consists of only 5 regions, or, more precisely, that only 5 of the 60 spaces of 10 Å each manifested mitogenetic effects (see fig. 24). There may be more than one spectral line, of course, in a strip of 10 Å. Recently, DECKER (1934) succeeded to to split the first double line of this spectrum into two different lines of 5 Å each.

The most important result, however, was the observation that these bands coincided exactly with those of the alcoholic fermentation by yeast, and also with those of the lactic fermentation by Streptococci. GURWITSCH concludes that there must be some process common to all of these sugar decompositions, giving off the same radiation. This seems probable since it is generally assumed that the cleavage of the hexose phosphate through glyceric aldehyde to methyl glyoxal is common to all three types of sugar decomposition.

As a consequence of these splendid findings, the method was used for a number of frequently-occurring biological reactions. After some preliminary analysis by LYDIA GURWITSCH (1931), BILLIG, KANNEGIESSER and SOLOWJEW (1932) produced the detailed proteolytic spectrum. Two sets of data were obtained, one with the digestion of serum albumin by the gastric juice of a dog, and another from the splitting of glycyl-glycine by erepsin. The two spectra proved to be exactly alike. The authors assume that the source of radiation is the deaminisation of the amino-acid group (see also Table 23 p. 74).

The splitting of nucleic acid by the pulp of adeno-carcinoma of a mouse has a spectrum decidely different from that of proteolysis. It was determined by A. and L. GURWITSCH (1932a) and is also shown in fig. 24 together with that of glycolysis and of an oxidation. The "nuclease" gives a very long wave length. The same lines have been found by GURWITSCH in the decomposition of lecithin by "lecithase" (unpublished; quoted from BRAUNSTEIN and SEVERIN, 1932). Since both enzymes split the phosphoric acid radical from the organic remainder, the Russian school now calls this the "phosphatase spectrum".

BRAUNSTEIN and SEVERIN (1932) attempted to analyze the spectrum of a different type of organic phosphate cleavage, namely that of amino-groups coupled with phosphoric acid in phosphagen. This, according to LUNDSGAARD, plays an important role in the energy for the working muscle. They prepared Ca-creatin phosphate from muscle, and its chemical decomposition by means of H_2SO_4 was the source of radiation. The spectral analysis was carried out by counting the total number of yeast cells (method, see p. 72). The final determination, in 10 Å strips, showed 8 with definite radiation. The line 2000—2100 is doubtful, and was considered negative by these authors, but has

subsequently been assumed as positive in all Russian publications. The mitogenetic spectrum of the working muscle (FRANK, 1929) contained some lines which at the time could not be accounted for, and which now can be explained by this phosphate cleavage.

These are the detailed spectra of simple chemical reactions published at present, as far as we have been able to ascertain. As oxidation spectra, the two double lines of pyrogallol oxidation have been inserted; these are commonly used by the Russian

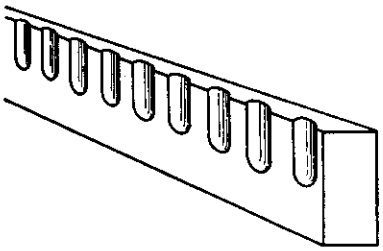

Figure 25.
Grooved glass block for exposing bacterial cultures to the various wave lengths of the spectrum, to be used with quartz plate in front, taking the place of the photographic plate in the spectrograph.

workers for this purpose. Fig. 24 shows that only rarely is the same line produced by two different processes. Even then, it should be realized that we are not dealing with true spectral lines, but with relatively broad regions, and that two identical strips do not necessarily indicate two identical lines, but rather two (or more) proximate lines.

There is also a spectrum shown which is the sum of all these processes. We shall see later (p. 156) that the spectra of nerves frequently combine all of these lines, in addition to some others of unknown origin.

The spectra of the action of amylase and maltase, and of sucrase (invertase) have been obtained by KLENITZKY and PROKOFIEWA (1934). The lines of these two enzymes agree to a much larger degree than any of the previously-mentioned processes. This is to be expected from their chemical parallelism.

Another method of obtaining spectra is that of WOLFF and RAS (1932) who used bacteria as detectors. They made a number of vertical grooves in a glass block which fitted into the camera of the spectrograph (see fig. 25); the grooves were covered by a quartz plate so that they became tiny pockets into which the detector culture was placed for exposure. The wave length for each one could be determined accurately.

By this procedure, they found the spectrum of neutralization of acid and alkali to consist of three lines

a strong line between 1960 and 1990 Å
a strong line between 2260 and 2300 Å
a weaker line between 2070 and 2090 Å.

Fig. 26 shows these regions, and also the spectra obtained by RAS (quoted from RUYSSEN, 1933) for the Bunsenburner flame. This latter spectrum has also been photographed, and had many more lines of longer wave length, some of which are shown

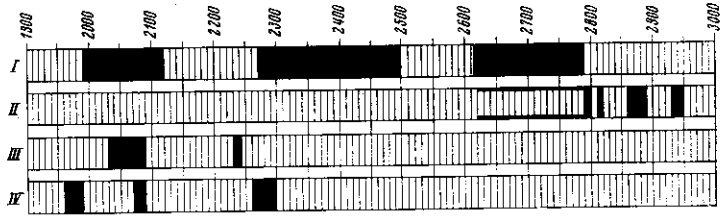

Figure 26. Photographic and mitogenetic spectra:
I. Bunsen burner flame, mitogenetic spectrum; *II.* same, photographic spectrum; *III.* Reaction $H_2 + Cl_2$, mitogenetic spectrum; *IV.* Reaction NaOH + HCl, mitogenetic spectrum.

here, but photography failed entirely at the shorter ultraviolet. — The figure also shows the biologically obtained spectrum of the reaction of hydrogen with chlorine.

It should not be gathered from this discussion that the indicated lines represent the entire spectrum of these reactions. On the contrary, it is most probable that it extends to both sides of the narrow range shown here. We are limited, however, by our indicators. Radiation below 1900 Å will be readily absorbed even by air (see p. 23), and that above 2600 Å does not produce mitogenetic effects (see fig. 28); therefore they can not be observed by the methods employed here. They may be capable of producing other biological effects hitherto unaccounted for, and may play an important part in chemical reactions.

A good summary of the Russian studies of mitogenetic spectra, including those of inorganic reactions, and with sufficient data to obtain a conception of the error of the method, has been given by A. and L. GURWITSCH (1934).

The intensity of ultraviolet radiation from a chemical reaction is not proportional to the total energy liberated. This was to be

expected because the same holds true for the emission of visible light from chemical reactions. Strong mitogenetic effects can be obtained from protein digestion by pepsin or from milk coagulation by rennet while RUBNER found the heat of reaction of proteolysis to be immeasurably small. On the other hand, the heat of neutralization of acid by alkali is so large that it can be observed even without a thermometer, yet its radiation is relatively weak.

The origin of the spectra is by no means clear. LORENZ's criticism (1934) can be explained in a concrete example as follows: If a spectrum represents the radiant energy emitted by the reaction as such, then each reacting molecule must emit at least one quantum of the shortest wave length observed in the spectrum. The longer wave lengths might originate from the shorter ones by loss of definite amounts of energy. Thus, in the case of sucrose hydrolysis by invertase (figure 24) each sucrose molecule must emit at least one quantum of the wave length 2020 Å, i. e. of the energy content 9.8×10^{-12} ergs (see Table 1). There are 6.1×10^{23} molecules in a grammolecule, or $\frac{6.1 \times 10^{23}}{342}$ in 1 g of sucrose. The minimal amount of radiant energy from 1 g of sucrose would then be:

$$\frac{6.1 \times 10^{23} \times 9.8 \times 10^{-12}}{342} \text{ ergs} = 0.175 \times 10^{11} \text{ ergs}$$
$$= 0.042 \times 10^{4} \text{ cal} = 420 \text{ calories.}$$

The total energy liberated by this hydrolysis has been measured by RUBNER (1913) by means of a BECKMANN thermometer in silverlined Dewar bottles, and was found to be 9.7 calories per gram. This experimental value is only one-fiftieth of the minimum amount calculated. It seems impossible that appreciable amounts of energy could have been lost by the method used. We are compelled to the following alternative: Either, the spectra do not originate from the reactions for which they are considered specific, but from some quantitatively unimportant side reaction; or, the calculated amounts are actually liberated, but are at once absorbed again.

This latter explanation does not appear entirely impossible. The biologist is familiar with "false equilibria", such as the stability of sugar in the presence of air, though it could be oxidized with liberation of much energy, and the process might, therefore, be expected to take place spontaneously. Modern chemistry

explains this by the necessity of "activation" of the molecule to make it react chemically. This activation requires energy. FRICKE (1934) in an introductory summary, makes the following general estimates:

"Generally, energies of activation are of the order of 100,000 gram calories per gram molecule which equals 1.5×10^{-19} gram calories per molecule. At ordinary temperature, the average kinetic energy of a molecule is of the order of 10^{-21} gram calories. Only the inconceivably small fraction of 10^{-43} of the molecules have energies in excess of 10^{-19} gram calories per molecule.

"The quantum theory gives as the reason that activation may be produced by radiation, the fact that the energy of the radiation is carried in a concentrated form, as quanta. The energy of a quantum of radiation is $5 \times 10^{-16}/\lambda$ gram calories where λ is the wave length in the ÅNGSTROM unit. The wave length has to be reduced to the order of 3,000 Å. before the quantum has the value 1.5×10^{-19} gram calories which, as we saw, represents the usual value for the energy of activation per molecule."

The energy of activation necessary for the hydrolysis of sucrose has not been determined. If we assume it to be of the "usual value" as computed by FRICKE it would be equivalent to a quantum of about 3,000 Å. wave length per molecule. When this is absorbed, the sucrose molecule hydrolyses, and the amount of energy thus released must be larger than that absorbed, because of the additional heat of reaction of 9.7 calories per gram. The free energy will be absorbed at once by a neighboring sucrose molecule which becomes activated, and hydrolyzed, and thus the reaction goes on. In this way, all the liberated energy is again absorbed, except for the difference between heat of hydrolysis and heat of activation which we measure as heat of reaction.

However, there is another small "leak". Of those molecules adjacent to the walls of the vessel, the energy may radiate into the wall rather than to another sucrose molecule, and these few quanta would leave the system, and produce a radiation if the vessel is transparent. The amount of energy thus leaving the vessel would be extremely small, and would be of a wave length equal or shorter than that required for activation.

If this explanation of the mitogenetic spectra is correct, they would be an excellent means to measure the energy of activation.

C. SECONDARY RADIATION

A phenomenon must be recorded here which was first believed to be typical of living organisms, but is a property of certain chemical solutions, or systems, namely the emission of rays from a solution as a response to "primary" rays directed upon it.

The first purely chemical effect of this kind was observed by A. and L. GURWITSCH (1932b) with nucleic acid. A 3% solution of nucleic acid was gelatinized in a glass trough. At one end, it was irradiated with the lines 3220—3240 Å from a copper arc, through a monochromator. At the other end of the trough, radiation of the nucleic acid could be observed, but the wave length of this "secondary" radiation was not the same as that of the primary; it was between 2450 and 2500 Å, which is the spectrum of nucleic acid hydrolysis (see fig. 24). This proves that it can not be merely a reflection of light, because the wave length changed, nor is it a case of fluorescence, for the secondary radiation has a shorter wave length than the primary. And most remarkable of all, the induced light may be stronger in intensity than the primary source.

The best explanation is most probably the one given by GURWITSCH that the primary radiation induces some kind of chain reaction (see p. 47) which is then radiating with its own spectrum. This would account for the difference in wave lengths as well as for the increase in intensity.

Other examples have been given by WOLFF and RAS (1933b). These authors observed the same effect with sterile blood serum. They found also that sterile nutrient broth did not produce secondary radiation, but showed it when bacteria had grown in it, even after the bacteria themselves had been removed by filtration through a porcelain filter. A very short action of living bacteria suffices to change the broth to a "secondary sender". These filtrates as such emit no primary radiation. WOLFF and RAS observed further that after long exposure to primary radiation, these liquids ceased to produce secondary radiation. Very intense primary light caused a more rapid exhaustion. 45 minutes exposure of a staphylococcus supsension to a strong primary sender had made it unfit to produce secondary rays; however, on the next day, the suspension reacted normally again. In another case, even 30 minutes exposure was sufficient to destroy the power of secondary radiation.

Nucleic acid solutions also cease to function when overexposed, and during this stage, they do not transmit mitogenetic rays. Strong solutions recover again after 1 or 2 days of "rest".

An important observation is that with increasing concentration of the acting substances, the secondary radiation becomes weaker. Table 12 represents an experiment with nucleic acid, by WOLFF and RAS. The source of primary radiation was the reaction of milk with rennet. The intensity of secondary radiation from the nucleic acid dilutions was measured by the length of exposure required to produce a "mitogenetic effect", i. e. to accelerate the growth of bacteria. The numbers in the table represent the percentage increase in cells over the control.

Table 12. Intensity of Secondary Radiation of Nucleic Acid solutions, measured by the time required to produce a "mitogenetic effect"

Concentration of Nucleic Acid, in %	Mitogenetic Effect after Irradiation for										
	15″	30″	1′	1.5′	2′	3′	4′	5′	6′	7′	8′
1.000							0	32	0	0	0
0.750							40	26	0	0	
0.500					33	55	12				
0.250		0	27	21	0		0				
0.100		0	43	17							
0.020		25	32	0							
0.004	0	0	0								
0.001	0	0	0								

The results are somewhat surprising. The lowest efficient concentration was 0.02%, which produced a mitogenetic effect at least 5 times as strong as the 1% solution, i. e. it produced the same effect in one-fifth the time. A similar relation was observed with bacterial suspensions. The more dilute they are, the stronger is the secondary radiation they emit upon excitation by some primary source. Perhaps this is brought about by the absorption of rays in overexposed solutions (see above).

Bacterial suspensions and their filtrates lose the power of secondary radiation upon heating; nucleic acid solutions do not.

The increase in intensity by secondary radiation enabled WOLFF and RAS to construct an "amplifier" for mitogenetic rays.

They placed six quartz cuvettes filled with staphylococcus suspension side by side, and by irradiating one side of the series, obtained a good mitogenetic effect from the opposite side in 10 seconds; the same primary source used for direct irradiation of the same detector required 4.5 minutes. This means an amplification of 27 times. The observation is added that one continuous column of the same length as all 6 cuvettes together, does not give a greatly increased intensity.

It must be kept in mind that the intensity of radiation has been ascertained only biologically, by the time required to produce a mitogenetic effect. It has already been pointed out (p. 24) that the reciprocity law (requiring double exposure time for half the intensity) does not even hold for such simple reactions as those in the photographic plate when the intensity becomes very low. Its application to biological reactions is quite doubtful. Recently, WOLFF and RAS (1934a) could show that usually, secondary radiation is polarized, and they also proved that polarized mitogenetic rays exert a very much stronger effect upon organisms. It is not at all certain, therefore, that the above statements really indicate an increase in intensity of radiation in the physical sense of the word.

In his most recent summary, GURWITSCH (1934) makes the following statement:

> "It has been found that all substrates capable of enzymatic cleavage, such as glucose, proteins, nucleic acid, urea, fats etc. react also upon mitogenetic radiation and become radiant. This "secondary radiation" has certain properties of great interest: (1). it travels from the irradiated part through the liquid medium to distances of several centimeters with the measurable speed of a few meters per second; and (2). the radiation is resonant, i. e. the substrate reacts mostly upon those wave lengths which it emits when decomposed enzymatically."

The only published experimental proof for this is that by DE KORÖSI (1934) as far as the authors have been able to ascertain.