spect the ampulla when a local diathermy excision of the polyp could have been carried out as advised by Cattell (Cattell and Pyrttek, 1950).

Commentary

I feel that the brief reports of these eight cases offer their own lessons, but would like to summarize shortly my own opinions.

In a case of obstructive jaundice in which there is some doubt as to the cause at laparotomy:

1. When the gall bladder is collapsed a careful dissection in the porta hepatis may reveal a growth. Usually little can be done but I would suggest that by opening the duct below and dilating the malignant stricture, palliation may be achieved with temporary clearance of the jaundice.

2. When the gall bladder is distended the duodenum and head of pancreas should be freely mobilized and the bile duct brought under direct vision. If there is a growth and it is absolutely confined to the bile duct a local resection is advised. If it appears to have spread outside the confines of the duct and involved the pancreatic head, a pancreatico-duodenectomy should be performed.

3. Where a lesion of the ampulla is suspected and there is the slightest doubt as to its nature, a transduodenal inspection should be made after mobilizing the duodenum. If doubt still exists, and facilities for frozen sections are available, a diathermy excision should be performed and the

treatment will be dependent on the pathological report.

Having performed a resection of one sort or another, the bile duct should be anastomosed to the jejunum, and this is much easier to perform over a soft rubber tube. The portion of jejunum should always be defunctioned (Figs. 5 and 6) to obviate the danger of ascending cholangitis. I have found that ligation of the proximal end of the duct and usage of the gall bladder to re-establish biliary continuity is unsatisfactory, the danger being that the bile duct will slough and the patient succumb to a biliary peritonitis.

The decision to perform a one- or two-stage operation depends upon the age and general condition of the patient. A one-stage operation is preferable but when the liver function is demonstrably poor a two-stage procedure is necessary. We have found that the most useful liver function tests are serum protein, thymol turbidity and alkaline phosphatase estimations.

In conclusion I would like to say that although these are relatively rare tumours they are as common as carcinoma of the gall bladder and as carcinoma of the pancreas (Willis, 1948). Their identification may often mean the saving of life by a relatively simple surgical procedure.

I am grateful to Mr. Norman C. Tanner for giving me access to his notes, and to Mrs. Macdonald and Miss Mason of the photographic department of St. James's Hospital.

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ATOM BOMBS AND RADIATION INJURIES*

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The story of Hiroshima and Nagasaki is now ancient history. It is well known that the two atomic bombs killed about 100,000 people and injured as many more, besides producing untold material damage. Of those who were killed about

80 per cent. died from burning or from mechanical injuries due to blast damage, which are the normal accompaniments of any explosion. There remained a smaller number, variously estimated at from 10 to 20 per cent., who were uninjured or trivially injured at the time, but who died days or weeks later from the effects of radioactivity.

Radioactivity then is a relatively minor cause of

* Part of this article has been taken from 'Some Medical Aspects of Atomic Warfare,' G. D. Wedd, *Public Health*, June 1950.

casualties following atomic bombing, and if a great deal of attention is devoted to it in the following pages it is because it is something new in a weapon of war and its effects are not generally known.

Nuclear Considerations

Before we can understand the medical effects of atomic warfare it is necessary to know a little about the physics of the atomic bomb and the nature of the radiations it emits.

Isotopes

Atoms are miniature planetary systems with tiny particles describing orbits about (relatively) heavy nuclei. These particles are negatively charged and are called electrons. Nuclei are made of protons and neutrons, the former are positively charged the latter uncharged. Each has a mass of about one mass unit, or 1,840 times the mass of an electron.

The number of protons in the nucleus is fixed for a given element. Thus chlorine always has 17 protons in its nucleus. The number of neutrons, however, is not fixed, but can vary between certain limits. For example chlorine can have either 18 or 20 neutrons in its nucleus. Hence chlorine atoms are not all of the same mass, some weigh 35 units (17 + 18), others weigh 37 units (17 + 20), and we distinguish between them by writing Cl^{35} and Cl^{37} respectively. Atoms of the same element with different masses, due to the different numbers of neutrons in their nuclei, are called isotopes. Isotopes have the same chemical properties since they are forms of the same element, but their physical properties differ somewhat. In particular they behave differently in nuclear reactions.

Radioactivity

All the heaviest atoms, and a few of the lighter ones, are radioactive. That is to say that they are continually breaking down ('decaying') because the arrangement of protons and neutrons in their nuclei is not quite stable.

If the neutron:proton ratio is too small, two neutrons and two protons are emitted together in the form of a particle called an 'alpha particle.' This, in fact, is a fast-moving helium nucleus with a mass of four units and a double positive charge. An example is the decay of radium into radon: $\text{Ra}^{226} \rightarrow \text{Rn}^{222} + \alpha (\text{He}^4)$. Alpha particles have a range of a few inches in air and a few thousandths of an inch in body tissue.

If the neutron:proton ratio is too large, a neutron changes into a proton with the emission of an electron called a beta particle. For example, actinium changes into thorium: $\text{Ac}^{227} \rightarrow \text{Th}^{227}$

+ β . Beta particles have a range of a few yards in air and a few tenths of an inch in body tissue.

Sometimes a nucleus emits excess energy in the form of electromagnetic radiation called gamma rays, which are identical with hard X-rays. These travel with the speed of light and have such a long range that they killed a number of people a mile away from the explosions in Japan.

Ionization

All these radiations from radioactive substances have the power of removing electrons from any atom which they encounter. The atom thus becomes positively charged and is called a positive ion. (An atom which had gained an electron would be called a negative ion.) It is because of the ionization produced in living tissue that radiations are harmful; it is also because of their ionizing power that they can be detected and measured.

Nuclear Reactions

In 1919 Rutherford succeeded in changing a few atoms of nitrogen into oxygen by bombarding nitrogen nuclei with alpha particles. $\text{N}^{14} + \text{He}^4 \rightarrow \text{O}^{17} + \text{H}^1$, a proton (hydrogen nucleus) being emitted. During the next 20 years a large number of reactions of this type were achieved. In particular it was found that neutrons were very effective in causing nuclear changes.

Energy Exchanges

When a nuclear reaction occurs the total mass of the products is often less than that of the reactants. Einstein showed that this apparent loss of mass appears as energy, according to the relation $E = mc^2$.

If E = energy in ergs, m = mass in grams, then c^2 is the square of the velocity of light in cm. per sec., i.e. numerically $c^2 = 900,000,000,000,000,000 = 9 \times 10^{20}$.

Fission

In 1939 it was found that when a rare isotope of uranium, U^{235} , is bombarded with neutrons, the nucleus absorbs one of them and becomes so unstable that it breaks up into two fragments. A good deal of energy is released in the process and, also, two or three neutrons are released at the same time. If these released neutrons fall on other U^{235} nuclei, further fission will occur and we shall have a 'chain reaction.'

There are, however, two difficulties which must be overcome before the chain reaction will proceed. First, any impurities in the lump of uranium may capture some of the neutrons, in which case fission will not occur. Second, any neutrons which escape through the surface of the uranium will be

lost and again will not cause fission. The first difficulty we overcome by making our material as pure as possible, but this is not at all easy. U^{235} occurs to about 0.7 per cent. in natural uranium, which is nearly all U^{238} , and we cannot use chemical methods to separate them since they are isotopes of the same element. Physical methods, such as the difference in diffusion rates of their gaseous compounds, are very tedious and inefficient, involving thousands of repetitive processes. Escape of neutrons depends on surface area, whereas capture depends on volume. If we increase the size of our lump we increase volume relative to area, and thus by having a lump of material greater than a certain 'critical size' we can reduce escape to an acceptable level.

The Bomb

If we have a lump of U^{235} which is less than the critical size it is quite safe. But if we have a lump greater than the critical size it will explode, since there are always a few neutrons present from spontaneous fission. The bomb may, in fact, consist of two lumps of U^{235} , each just less than the critical size, which are brought suddenly together when the bomb is detonated.

Since it is very difficult to prepare pure U^{235} an artificial element, plutonium, is used instead. A controlled chain reaction is used in an 'atomic pile' to provide a steady neutron bombardment of U^{238} ; plutonium is the result of this reaction.

Fission Products

When fission takes place the nuclei do not always split in the same way, so that the fragments ('fission products') are of different sizes. These fission products are unstable, since they contain too many neutrons, and decay rates vary enormously among them, but it is found that the decay curve of a typical mixture of fission products from an atomic bomb falls very rapidly at first and very slowly later on. Roughly speaking the activity at a given time after the explosion varies inversely with time. For example the activity one hour after the explosion will be roughly one-sixtieth of that after one minute.

Induced Radioactivity

When an atomic bomb explodes, neutrons are emitted and these neutrons may react with various elements changing them into radioactive isotopes. An example of this occurs with sodium. $Na^{23} + n \rightarrow Na^{24} \rightarrow Mg^{24} \rightarrow \beta, \gamma$. This effect, however, is not of major importance.

Effects of the bomb

The fission of a few kilograms of uranium²³⁵ or plutonium releases energy equivalent to the ex-

plosion of about 20,000 tons of T.N.T. (Fig. 1). This energy is released in the form of:

1. An immediate heat flash sufficient to ignite dry material up to about 2 miles and to cause burns on exposed parts of the human body up to $2\frac{1}{2}$ miles on a cloudless day. However, this heat flash has a duration of not more than a few seconds, so that effective shielding is provided by quite thin material provided that it is light in colour and reflects most of the heat. It was found in practice that at ranges where survival was possible severe burns did not occur on clothed areas when the clothing was light in colour.

2. A blast wave which destroyed all buildings, except those strongly constructed of reinforced concrete, up to $\frac{1}{2}$ mile and cracked ordinary brick buildings up to $1\frac{1}{2}$ miles.

3. A 'flash' of gamma rays which killed about half the people exposed at $\frac{3}{4}$ mile and a few at 1 mile.

After the air burst there was no significant residual radioactivity in the neighbourhood, because all the radioactive substances were carried high up in the air from where they were eventually dispersed so diluted as to be harmless. That would not be the case after a ground burst or an underwater burst, either of which would result in heavy contamination of the site.

Radioactive Contamination

Radioactive contamination of ground following an atomic bomb or the spraying of fission products is always a possibility for which we must be prepared. Anyone who enters such a contaminated area exposes himself to two additional dangers which need not be considered when dealing with gamma rays from an atomic bomb.

1. He is now exposed to bombardment by beta particles which must be added to the effect of the gamma rays.

2. There is the much greater danger of radioactive substances being absorbed into the body either by inhalation or swallowing, and this includes the unexploded part of the bomb which emits alpha particles. Many of these alpha and beta emitters are heavy materials which are eventually deposited in the skeleton from which they are excreted extremely slowly, and there is not much that can be done about it. The ill effects of such absorption may not be noticed for some years but, given time, a fantastically small amount of some radioactive substances may be fatal. It is probable that the lethal dose of plutonium is not more than about $10 \mu\text{gm.}$, and some of its fission products are nearly as dangerous.

Both these dangers can be largely avoided with care. Suitable protective clothing must be worn

FIG. 1.—Effects of an atomic explosion.

to prevent radioactive substances from coming in contact with the body and from being inhaled or swallowed. Before any work is permitted the area must be surveyed by a specially-equipped monitoring party who will record the level of activity and say what length of exposure is acceptable.

Effects of Radiation on Living Organism

The exact means by which penetrating radiation damages the body is not fully understood, but it will be sufficient for our purpose if we say that it is through the formation of ions in the tissue. One of the most characteristic properties of this radiation, whether it consists of alpha or beta particles, neutrons, X or gamma rays, is that of stripping one or more electrons from an atom in whose neighbourhood it passes and so producing ions. If it were not so their presence could not be detected.

Since the ionization of an atom leads to the decomposition of a molecule of which it forms a part, we can understand how a gamma ray passing through the body leaves a trail of destruction behind it. The effect is insidious and any change produced may not be noticed for some time.

Firstly, the decomposition of protein molecules in the tissues deprives us of their services and gives rise to a number of breakdown products, some of which are toxic. Thus we can explain the inactivation of enzymes, which has been observed experimentally, and the shock-like symptoms and vomiting which have occurred within an hour or so of heavy irradiation both in human casualties and in experimental animals.

Secondly, there is good experimental evidence that an ionizing particle or ray passing through the substance of a chromosome can break it at the point of passage. Such broken chromosomes tend

to heal in a short time, but if there are many broken ends in the same place the wrong parts may join up. Naturally, the heavier the irradiation the more broken ends there will be. If a chromosome is broken it appears that the two ends can function quite well unless the cell starts to divide. When division occurs the fragments fail to reach their appointed places. There is a serious disturbance in the chromatin complement of the daughter cells which are usually inviable.

From these considerations certain important consequences emerge.

1. Tissues composed of cells which are actively dividing, such as blood-forming organs, gonads and mucous membrane, are much more radio-sensitive than those whose cells have ceased to divide, such as nerve and muscle.

2. There is usually a 'latent' period of some days between the irradiation and the signs of more serious damage. This latent period represents the time taken for the bulk of the damaged cells to divide.

3. A single large dose of radiation is much more dangerous than the same amount spread over a longer time or taken in divided doses. In point of fact an X-ray worker may, during his life, receive without any ill effects at least twice the amount of radiation needed to kill him if he received it in a single dose.

Radiation Casualties

Atom bombs will be used for their explosive effect but, incidentally, produce a burst of ionizing radiation. Accordingly, among the ordinary air raid injuries from collapsing buildings and burns from heat flash and secondary fires, a new type of casualty will be seen as radiation illness. This is not fully developed until two to four weeks have elapsed, when it is seen as a combination of agranulocytosis, from bone marrow damage, and a haemorrhagic state.

It seems most probable that these bombs will be exploded at a height between 500 and 2,000 ft. over a town, in which case serious structural damage to buildings will be confined to an area within 2 miles of the ground centre, though minor damage, such as broken windows, may occur out to at least 4 miles. The intensity of gamma radiation at 1 mile will have fallen off nearly to a sub-damage level, with the LD₅₀ at about $\frac{3}{4}$ mile. From ground centre to $\frac{3}{4}$ mile it is to be expected that anyone surviving the explosion in the open will be very lucky, so that in proportion to the surgical injuries radiation casualties will be very few. However, at Hiroshima people did survive in a tram at 1,000 yards (Cogan, 1949) and in a ferro-concrete building at 250 yards (H.M.S.O., 1946), and some died later from the pure radia-

tion syndrome. If, therefore, there is warning and people are in shelters there may be several thousand primary survivors exposed to pure radiation injury.

For the radiation syndrome to develop there are two basic factors necessary:

1. That the victim should be exposed to the source so that the whole body is irradiated at once.
2. That the source should deliver several hundred roentgens in less than two hours, of rays of such energy that ionization is evenly distributed throughout the tissues.

These factors are not met with except during atomic explosions and in the event of careless exposure in the neighbourhood of high energy X-ray machines, so acute radiation sickness was not seen on a large scale in man before the Japanese bombing.

The duration of the burst of 'immediate radiation' is about 10 secs., during which time the intensity drops so that about half the dose is delivered in the first second and the remainder in the other nine. It looks as if one should be able to escape part of the gamma ray flash by taking refuge behind a wall or other heavy obstruction immediately the burst is seen. The same applies in a lesser degree to the thermal radiation.

The results of whole body exposure to radiation, which is not heavy enough to cause death within a few days, are seen in the form of damage to those tissues whose cells are most sensitive:

1. Blood-forming organs—lymph nodes and bone marrow.

2. Gastrointestinal mucosa.

To these must be added:

3. The gonads, though damage in this case is scarcely likely to endanger life.

The Blood-Forming Organs

The circulating cells, with the exception of the lymphocyte, are relatively resistant and the main damage falls on the immature cells. As a result the numbers of circulating cells fall, but not at once; the time taken is related to the normal lifetime of the cell. The early behaviour of the Japanese patients is not known with any accuracy since serious investigations were not undertaken until about the sixth week. However, such results as were obtained, combined with numerous animal experiments, suggest that the lymphocytes begin to decrease at once, reaching a minimum about the fifth day. The granulocytes may show an indefinite rise in the first three days and then begin to fall, reaching a minimum early in the second week. The extent of the fall is related to the dose of radiation, but there appears to be no limit to it since total white counts below 100 have been seen in Japan (Le Roy, 1950). However, recovery was

rare after lymphocyte counts below 200 or total white counts below 800 cu. mm.

If there is to be recovery it usually starts during the second month, and animal experiments have shown that those animals which die in the first 28 days from the direct effects of acute irradiation seldom show any tendency to recovery of white cells.

Platelets may begin to fall in the second week and counts below 25,000 were seen in some cases, but their behaviour has not been studied to the same extent as that of the other cells.

Red cells, which are relatively insensitive to radiation and normally live at least 100 days, are slow to fall. A marked decrease does not occur until about the fourth week, in the absence of haemorrhage, but may continue for a month or more if the patient survives. Recovery from the

resulting anaemia is always slow and is not likely to be complete for many months.

The direct consequence of the loss of leucocytes is infection, which is inevitable after severe radiation injury. A further effect on the circulatory system is the bleeding from the second to the fifth week, varying from petechiae to massive haemorrhage into the body cavities and from various orifices. A number of factors appear to be involved, including damage to the endothelium of the smaller blood vessels and an almost indefinite increase in the clotting time, due to loss of platelets and, perhaps, the liberation of a heparin-like toxin from damaged tissue.

The Gastrointestinal System

After severe irradiation, loss of appetite, nausea and vomiting are often seen on the first day, usually followed by early recovery. These changes are too early for the full effect of damage to cells to be felt and are probably due to some chemical mechanism. Towards the end of the first week, or later, the symptoms recur, often accompanied by diarrhoea, at first watery and later bloody. These symptoms are an indication of changes taking place throughout the alimentary canal, but more marked in the intestine than in the stomach. The early changes include hyperaemia and oedema, which may be so severe that large sections of the intestine look as if they had been dipped in boiling water. Later ulcers appear which bleed readily, and permit the infection of the body with intestinal organisms.

About the same time as the bloody diarrhoea, sore throat and ulceration of the mouth appeared such as occur in agranulocytic angina.

FIG. 2.—Estimated rates of fall of lymphocytes and granulocytes at different doses of ionizing radiation.

The Gonads

The question of the possibility of permanent sterility as a result of a single irradiation has received far more attention than its importance seems to warrant. The fact is that both testis and ovary are highly sensitive to radiation, and temporary sterility was a common finding in Japan in both men and women, though all who survived recovered within a year or so, so far as is known. The power of recovery of the testis is such that the single dose of radiation needed to produce permanent sterility is far greater than the lethal dose. The ovary is less sensitive than the testis in the first place, but it also has less power of recovery. The sterilizing single dose is probably about the same as the lethal, and permanent sterility in a woman who survives is possible but not very likely. The possibility of genetic changes will be mentioned later.

Treatment of Radiation Casualties

No first aid treatment is indicated for radiation casualties, apart from the other injuries they may have received. In order that they may receive adequate treatment they must be admitted to hospital, which will be made easier by the long latent period before the appearance of the symptoms.

In the event of an atomic attack it is likely that the casualties will number many thousands. This means that if an attempt is made to treat them all they will be treated inadequately, and many lives will be lost which might be saved by a selection of cases. There will always be a certain number for whom nothing can be done. These should receive no treatment beyond what is necessary for the relief of their symptoms. Likewise, many will be trivially injured and will recover without treatment. The main effort must be directed to those border-line cases who may recover with energetic treatment but not otherwise.

As prognostic indications the following may be helpful:

1. If the total dose of radiation received was less than 300 roentgens recovery is probable, if it was more than 600 r. the chances are very poor. It is quite likely that the dose received may be estimated approximately either from the patient's known distance from the bomb or from instruments. Unfortunately both these methods are subject to certain fallacies. If distance is used the estimation is based on the assumption that the patient was evenly irradiated in the open, whereas, in fact, part or all of his body may have been in the shelter of some solid structure. If he was indoors at the time it would be necessary to make allowances for such things as structure of walls and ceilings, position of windows and scatter from the

walls of the room. Instruments carried on the person should give a closer estimate, but only if it were certain that the instrument was exposed to the same extent as the rest of the body, which is unlikely to be the case. A great deal would depend on which way the patient happened to be facing at the time, whether the instrument was towards the burst or away from it. Further, the instrument might have been fully exposed while part of the body was protected. Installed instruments in buildings suffer from the disadvantage that there is no reason to suppose that radiation would be even approximately evenly distributed throughout a room, let alone the building as a whole. It is certain that one should hesitate to make up one's mind about the fate of a patient from the dose of radiation supposed to have been received.

2. Fever in the first week after irradiation with a step-like rise of temperature, in the absence of any other cause, means a grave prognosis.

3. A fall in the lymphocyte count below 200 per cmm. on the first day means there is almost no hope of recovery, whereas a count above 1,000 after three days probably means that the damage is trivial.

4. A total white count below 800 per cmm. after ten days means the patient will probably die, but if it is over 1,500 per cmm. he has a good chance of recovery.

5. If the white count is found to be rising at any time after the third day the chance of recovery is good.

6. Nausea and vomiting on the first day is a sign of serious, but not necessarily fatal, damage. If the vomiting recurs within the first five days accompanied by bloody diarrhoea the prognosis is very bad.

7. If there is no epilation by the end of the third week the patient will probably recover.

General Treatment

1. Complete physical and mental rest. This is necessary in view of Cronkite's (1949) finding that anything tending to raise the metabolic rate of mice diminished their chances of recovery from radiation injury. Sedatives and morphine may be necessary.

2. Prevention of chilling for the same reason.

3. Diet should be semi-solid and non-residue on account of the damage to mucous membranes and difficulty in swallowing. Protein should be sufficient to meet basal requirements, but excess should be avoided in the early stages owing to its specific dynamic action. Later, as recovery begins, the diet should be high in calories and protein. Liver extract should be useful at this stage.

4. Nursing care to avoid bed sores and other injuries which might act as portals of entry for bacteria.

5. Asepsis when using hypodermic or intravenous needles. Injections should be given as infrequently as possible in order to avoid infection and bleeding.

Specific Treatment

1. Penicillin will be needed to guard against infections. Probably the best way will be to use an oily preparation which retains its activity for two or three days and give an injection of 0.25 to 1 mega unit every other day. Streptomycin or

some other antibiotic may be needed in some cases to treat penicillin-resistant organisms, but streptomycin should not be used indiscriminately. Of the newer antibiotics aureomycin has given promising results in experimental animals and looks like being available in large quantities shortly.

2. Blood or substitutes. During the anaemic stage whole blood will be needed in amounts of about one to two pints per week according to the extent of the haemorrhage. At the same time dried plasma should be given, as necessary, to correct the low blood protein. Weekly or more frequent estimations should be done on the haemoglobin and plasma protein levels as a check on the treatment. If blood and plasma are not available in sufficient quantities the best substitute is probably dextran, a polysaccharide which can be prepared in large quantities, keeps indefinitely and is said to be non-toxic provided the optimum molecular size is selected.

3. Toluidin blue, protamine and rutin have all been used to diminish the bleeding tendency. Toluidin blue and protamine act by combining with heparin, and have been found to decrease the clotting time in animals. Unfortunately they were of no value in saving the lives of the animals in question. Rutin has the effect of diminishing capillary permeability. Good effects have been reported from its use in some animals, but only if the administration had started before the radiation. In other experiments it has been of no value whatever.

GRANULOCYTES IN PER CENT OF MEAN

FIG. 3.—Estimated rates of fall of lymphocytes and granulocytes at different doses of ionizing radiation.

4. Certain vitamin preparations, particularly pyridoxin and folic acid, are useful for relieving the symptoms after radiotherapy. It appears from animal experiments that they are only likely to assist in saving life if the administration begins before the radiation.

5. Suprarenal cortical extract is also favourably reported as relieving the symptoms after radiotherapy in a high proportion of cases.

6. Pentose nucleotide has been shown to be effective where active bone marrow is present, and in those cases where recovery is seen to have started it may hasten the process.

Although the above drugs have not helped to save the lives of animals after a lethal dose of radiation it is still possible that any or all of them may shorten the course of the illness in less severe cases, and they should be tried if they are not likely to do harm for other reasons.

Forms of treatment which might be expected to be useful on general principles but which have been disappointing in practice include vitamin K, bone marrow transfusion and leucocyte concentrates. Sulphonamides, when given internally, have done nothing but harm, but there may be a place for them in preventing infection of external wounds.

Long-Term Effects

If a patient makes an apparently complete recovery from a heavy dose of radiation it must not be assumed that he is necessarily safe. New growths in various parts of the body are to be expected after a long interval in a proportion of cases though, up to the present, there is no news of such complications from Japan. What has been found in Japan in the last two years is a small number of cataracts occurring mostly in those who were just over 1,000 yds. from the ground centre, and attributed to the effects of neutron bombardment.

Chronic Sub-Lethal Radiation

Apart from the immediate acute irradiation from the high air burst, we may have to cope with the more chronic effects on people working in areas which have been contaminated by an underwater explosion or by the dropping of fission products from some such vehicle as a rocket. If such an area were heavily contaminated it would have to be abandoned, but if the contamination were light and the work important the risk might be accepted. Alternatively, it might not be known that there was any contamination until some damage had been done.

It is generally accepted that a daily whole body exposure to about 0.1 roentgen will do no harm in an indefinite time. At about two to three times

that dose rate a few specially susceptible people might suffer from minor degrees of leucopenia. At dose rates around 5 r. per day more severe leucopenia would be common and probably also some degree of anaemia. Leukaemia would be expected to occur after a considerable interval in a proportion of such subjects.

Skin changes may be expected in the form of atrophy or proliferation after repeated excessive doses, but at what level it is not clear. That the level is probably high is suggested by American evidence. It was found as a result of a questionnaire that a large proportion of radiologists of more than five years' standing were found to have changes in their finger ridges, such as atrophy, proliferation and fissures. An attempt to produce similar changes in monkeys was successful, but not until about 1,000 r. had been given in divided doses at about 20 r. a sitting.

In dogs deformed sperms and low sperm counts have been found as a result of repeated irradiation at dose rates below 1 r. per day. However, complete recovery followed the stopping of the exposure. The power of recovery of the testes is very great and sterilization is unlikely to follow exposure at low dose rates. The ovary has much less power of recovery and it is possible that damage might be done in time at rates not much above the maximum permissible dose rate. In fact it has been suggested that the maximum permissible dose rate should be considerably lower for women.

If the daily rate is somewhere about 25 r. per day we step out of the chronic zone and all the effects of acute irradiation may be expected to occur after about 400 r. to 500 r. have been received.

Genetic Effects

The genetic effects of radiation are expected to take the form of an increase in the normal number of mutations.

Mutations due to some chemical change in a gene or a system of genes occasionally occur spontaneously as when a black or a white rabbit arises from wild stock, or when a case of polydactyly or haemophilia suddenly appears in a human family. Few genetic experiments have been done with vertebrates, but a great deal of work has been done on invertebrates, particularly the fruit fly, *Drosophila*. In *Drosophila* a number of mutations are known to occur with considerable regularity, and it may be said that the chance of a mutation occurring in any particular gene is between 1 in 100,000 and 1 in 1,000,000 per generation. This chance can be increased by changes of temperature, by certain chemicals and, above all, by irradiation. For those organisms

which have been extensively studied, the amount of radiation needed to double the number of mutations they produce is about 40 r. to 50 r. or the amount received by a human worker who keeps just below the tolerance dose for two years.

Since nearly all mutations are subnormal in some respect the conclusions to be drawn from the foregoing might be truly alarming if it were not for certain redeeming features.

Firstly, many mutations are lethal. This means that if a man receives from 40 r. to 50 r. he may produce an additional small fraction of 1 per cent. of infertile sperms. If the whole population receive the same dose the general birth rate may decrease by the same small fraction of 1 per cent.

Secondly, nearly all viable mutations are Mendelian recessives. They will not be noticed in the developing organism except in the extremely unlikely case where both parents receive the same

altered gene.
It has been estimated that at the present rate of irradiation of the whole population there may be a serious increase of deleterious mutations in from 20 to 40 generations.

Summary

Some account is given of the casualties produced by atom bombs. Of these a relatively small number are due to ionizing radiation. The action of ionizing radiation on living organisms is described, with the clinical syndrome of radiation sickness. The organs most affected are the haemopoietic system and the gastrointestinal mucosa, and the symptoms which arise are due to damage to those organs. An attempt has been made to estimate the prognosis of radiation casualties and suggestions are given about their treatment.

SUMMARY OF CLINICAL SYMPTOMS OF RADIATION SICKNESS
From 'Effects of Atomic Weapons'

Time after exposure	Lethal dose (600 r.)	Median lethal dose (400 r.)	Moderate dose (300-100 r.)
First week	Nausea and vomiting after 1-2 hours	Nausea and vomiting after 1-2 hours	No definite symptoms
	No definite symptoms	No definite symptoms	
	Diarrhoea Vomiting Inflammation of mouth and throat		
Second week	Fever Rapid emaciation Death (Mortality probably 100 per cent.)	Beginning epilation	No definite symptoms
Third week		Loss of appetite and general malaise Fever	
		Severe inflammation of mouth and throat	Epilation
			Loss of appetite and general malaise
			Sore throat
Fourth week		Pallor Petechiae, diarrhoea and nose bleeds	Pallor Petechiae Diarrhoea
		Rapid emaciation Death (Mortality probably 50 per cent.)	Moderate emaciation (Recovery likely unless complicated by poor previous health or super-imposed injuries or infections)

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