extending the hand into a well-defined beam of radiation, and in practice local overexposures may readily occur. However, such local exposures are much more apt to be accidental, or the result of carelessness, whereas the whole-body exposure originates from the difficulty of screening this type of radiation. Consequently, workers engaged in the application of x-rays and gamma rays in industrial plants are subject to both types of exposure.

B. LATENT PERIOD

From our introductory discussion of current ideas as to how radiation can produce injury to living tissue, it is apparent that the full effects of irradiation will not be manifest at once. The destruction of cells in a complicated assembly such as human tissues will set in motion a train of events that may reach a culmination weeks or months after the exposure. Since not every cell in the tissue affected is destroyed by radiation, as would be likely to be the case in a burn produced by excessive temperature, the tissue begins to exhibit the deficiencies resulting from the occasional destruction of isolated cells only after a period of development during which the injured or obliterated cells obstruct normal growth. Consequently, one of the most striking characteristics of injuries arising from penetrating radiation is the latent period that always intervenes between the exposure and the visible manifestations of its effects. We are all familiar with the same general process in ordinary sunburn, in which the burn develops several hours after exposure. In the case of gamma rays, this latent period extends to several days, even when the effect produced is in surface tissues, as in an erythema, and many effects may develop much later. This is particularly true of malignancies that originate from exposure to radiation.

Because of this latent period there is no warning of injury at the time of exposure, even for local injuries that are severe enough to develop into painful and crippling burns. It is only by habitual regard for definitely safe procedures that persons working with sources of penetrating radiation, such as accelerators or radioisotopes, can escape injuries of various kinds. These injuries may be a slight or severe erythema and, from greater exposures, a deep deterioration of underlying tissues causing a permanent deformity. In another category are injuries, such as keratoses, malignant growths, and even deep-seated cancers, that develop over a period of years and do not produce detectable effects, in some instances, until they have reached an advanced stage. We also know that large doses of penetrating radiation, whether received as a single massive dose or distributed over a long period, will produce noticeable disturbances in the blood count. If the dose is large enough, anemia or leucopenia may occur almost immediately. Either disease can reach a fatal stage unless the exposure is interrupted and restorative measures applied in time.

C. TOLERANCE DOSE

Whereas local injuries from penetrating radiation can be avoided by careful habits of work and suitable protective screens, the prevention of excessive exposure over the whole body must be based on a knowledge of the dosage that will not produce detectable injury. Admittedly, the information on this subject is somewhat scanty and is based entirely on accumulated experience over the past fifty years.

The question of permissible levels of radiation has received a great deal of attention since the development of nuclear reactors with their ability to produce enormous amounts of radioactivity. One result has been to modify the use of the roentgen to take account of the variation in the biological effects of different types of radiation. This has also led to the definition of a companion unit called the "r.e.p." (roentgen-equivalent-physical) defined as the amount of radiation that, on absorption in soft tissues, delivers 93 ergs per gram of tissue. This arises from the fact that the roentgen, defined as the amount of x-radiation or gamma-radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying 1 electrostatic unit of electricity of either sign, delivers 83 ergs per gram of air. This same radiation has been found to deliver 90 to 110 ergs per gram in various tissues. The use of the r.e.p. to replace the roentgen has the practical effect of slightly reducing the tolerance limits, as stated in the same number of roentgens.

There are small divergences in the recommended maximum limits of radiation exposure among those customarily dealing with large-scale operations in this field. Perhaps the most generally accepted are those recommended by the International Commission on Radiation Protection in 1950, summarized in Table 1.

TABLE 1
Maximum Permissible Radiation Exposures[a]

Radiation	RBE	No. of r.e.p. per week		
		At any point in body	In basal layer of epidermis	
			Entire body	Hands
X- and γ-rays	1	0.3	0.5	1.5
β-rays	1	0.3	0.5	1.5
Protons	10	0.03	0.05	0.15
α-rays	20	0.015	0.025	0.075
Fast neutrons	10	0.03	0.05	0.15
Thermal neutrons	5	0.06	0.1	0.3

[a] Because of changes in recommendations resulting from new information on potential damage from radiation, frequent revisions of these data can be expected. These revisions are usually announced in journals in the field of radiology and radiation protection.

The relative biological effectiveness, RBE, in the second column is merely a rough estimate of the relative amount of damage which one roentgen of the radiation will produce in tissue. The value for thermal neutrons is particularly open to question. This estimate of RBE as shown by the numerical values controls the recommended exposure, relative to gamma-rays in each case.

In regard to ingestion or inhalation of radioactive substances, there is no simple way to arrive at a maximum safe quantity to be carried in the body. For