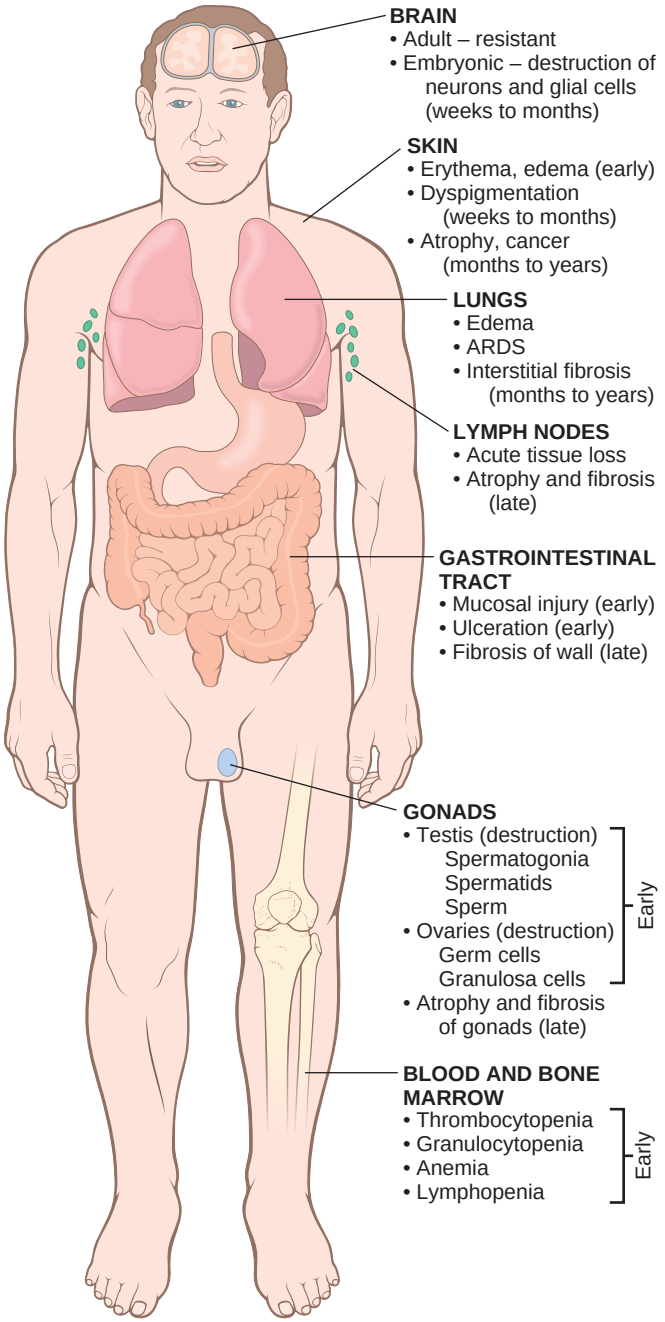

Figure 9-18 Overview of the major morphologic consequences of radiation injury. Early changes occur in hours to weeks; late changes occur in months to years. ARDS, Acute respiratory distress syndrome.

Total-Body Irradiation. Exposure of large areas of the body to even very small doses of radiation may have devastating effects. Doses below 1 Sv produce minimal symptoms, if any. However, higher levels of exposure cause health effects known as *acute radiation syndromes*, which at progressively higher doses involve the hematopoietic, gastrointestinal, and central nervous systems. The syndromes associated with total-body exposure to ionizing radiation are presented in Table 9-8.

Acute Effects on Hematopoietic and Lymphoid Systems. The hematopoietic and lymphoid systems are extremely susceptible to radiation injury and deserve special mention. With high dose levels and large exposure fields, *severe lymphopenia* may appear within hours of irradiation, along with shrinkage of the lymph nodes and spleen. Radiation kills lymphocytes directly, both in the circulation and in tissues (nodes, spleen, thymus, gut). With sublethal doses of radiation, regeneration from viable precursors is prompt, leading to restoration of a normal blood lymphocyte count within weeks to months. Hematopoietic precursors in the bone marrow are also quite sensitive to radiant energy, which produces a dose-dependent *marrow aplasia*. The acute effects of marrow irradiation on peripheral blood counts reflects the kinetics of turnover of the formed elements—the granulocytes, platelets, and red cells, which have half-lives of less than a day, 10 days, and 120 days, respectively. After a brief rise in the circulating neutrophil count, *neutropenia* appears within several days. Neutrophil counts reach their nadir, often at counts near zero, during the second week. If the patient survives, recovery of the normal granulocyte count may require 2 to 3 months. *Thrombocytopenia* appears by the end of the first week, with the platelet count nadir occurring somewhat later than that of granulocytes; recovery is similarly delayed. *Anemia* appears after 2 to 3 weeks and may persist for months. Understandably, higher doses of radiation produce more severe cytopenias and more prolonged periods of recovery. Very high doses kill marrow stem cells and induce permanent aplasia (*aplastic anemia*) marked by a failure of blood count recovery, whereas with lower doses the aplasia is transient.

Fibrosis. A common consequence of radiation therapy for cancer is the development of fibrosis in the tissues included in the irradiated field (Fig. 9-19). Fibrosis may occur weeks or months after irradiation as a consequence of the replacement of dead parenchymal cells by connective tissue, leading to the formation of scars and adhesions. Vascular damage, the death of tissue stem cells, and the release of cytokines and chemokines that promote inflammation and fibroblast activation are the main contributors to the development of radiation-induced fibrosis (Figs. 9-20 and 9-21). Common sites of fibrosis after radiation treatment are the lungs, the salivary glands after radiation therapy for head and neck cancers, and colorectal and pelvic areas after treatment for cancer of the prostate, rectum, or cervix.

DNA Damage and Carcinogenesis. Ionizing radiation can cause multiple types of DNA damage, including single-base damage, single- and double-stranded breaks, and

Table 9-7 Estimated Threshold Doses for Acute Radiation Effects on Specific Organs

Health Effect	Organ	Dose (Sv)
Temporary sterility	Testes	0.15
Depression of hematopoiesis	Bone marrow	0.50
Reversible skin effects (e.g., erythema)	Skin	1-2
Permanent sterility	Ovaries	2.5-6
Temporary hair loss	Skin	3-5
Permanent sterility	Testis	3.5
Cataract	Lens of eye	5

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