he concluded that the nature of the affliction was so unusual that it must result from some type of occupational poisoning, and published a statement to this effect.[10]

In the following year, Hoffman,[11] who was asked to investigate the plant in New Jersey where girls were employed to apply radioactive paint, found from an examination of death certificates of deceased former employees that these certificates were strikingly similar, although made out by different family physicians, who were entirely ignorant of the true cause of death.

There was frequent mention of jaw necrosis, anemia, and buccal lesions, although the immediate cause of death was usually given as some well-known disease that exhibits some of these symptoms. It was highly improbable, in Hoffman's opinion, that this could be accidental. After he had assembled data on five deaths and twelve living cases, where infected jaws and anemia were predominant features, he concluded that they represented a new type of occupational poisoning, since all cases had worked at the same plant. From his investigations of the working conditions and the nature of the material applied by these workers, he also formed the opinion that the mesothorium in the paint had something to do with the symptoms observed. This opinion was further confirmed in his mind by the observation that after dipping their brushes in radioactive paint the girls habitually pointed them between their lips. This practice would give an excellent opportunity for ingestion of the paint.

These preliminary reports led to a series of investigations, sometimes with contradictory conclusions. In most of these investigations, the radioactive component of the paint was ignored and some other source of the disease was sought. However, in the same year Martland[12] examined two girls who were suffering from extensive jaw necrosis and anemia. Both girls died and, as a result of autopsies which he performed, and investigations on living patients suffering from the same symptoms and engaged in the same work, he was able to formulate an extensive report which clearly, for the first time, traced the disease to its true origin.[13] From an examination of expired air, he was able to detect the presence of radon by the large number of alpha particles revealed by a zinc sulfide screen in a darkened room when the subject breathed against it. From the skeletons, after death, he proved the presence of radioactive material in the bones by electroscopic and photographic tests. By chemical extraction methods he recovered 150 micrograms of radium from one skeleton. At the same time, from examination of patients suffering with the disease, he was able to describe more accurately the type of anemia, and the nature and progress of the bone lesions. In this way, he accumulated information that would provide easy means of identification of the disease from the symptoms. As a result of this clarification of the picture, it became evident that deaths of workers as early as at least 1922 had been the result of radium poisoning, although attributed by family physicians to other diseases.

[10] T. Blum, *Am. Dental Assoc.* (1924).
[11] F. E. Hoffman, *J. Am. Med. Assoc.*, *85*, 961 (1925).
[12] H. S. Martland, P. Conlon, and J. P. Knef, *J. Am. Med. Assoc.*, *85*, 1769 (1925).
[13] H. S. Martland, *J. Am. Med. Assoc.*, *92*, 466, 552 (1929).

It is of interest to consider the general environment under which these tragic circumstances developed, in which undoubtedly more than two score persons lost their lives within a brief span of years, and many others were afflicted with crippling injuries that undoubtedly brought on death at an untimely age. In the period of World War I and immediately thereafter, about 800 girls, at one time or another, were employed in one plant in New Jersey painting the dials of clocks and instruments. There was a considerable demand for such articles for military use and, in the expansion of the industry, workers were recruited from other types of employment where similar skills were required. They usually were paid in accordance with the number of articles they completed per day, and were not specifically warned of any particular hazard, since the dangers from the ingestion of radium were not then understood. Consequently, they adopted procedures that would enable them to produce acceptable work at the most rapid rate. Many of these workers had applied other types of paint, in previous employment, which were not sufficiently toxic to produce any ill effects if the fine brushes were pointed by means of the lips. They soon discovered that this was a very effective procedure in radium dial painting. Since the paint consisted chiefly of zinc sulfide suspended in a water solution of gum arabic, occasionally thinned with water to give proper working consistency, there was no natural deterrent to the procedure. The amount of radium that a worker might ingest under these circumstances has been estimated at from 15 to 200 micrograms per week. This explains in a few words how the situation developed. Early in the investigation, the employers sensed that radium poisoning might be the cause of the deaths and injuries, which were rapidly mounting, and ordered the practice of tipping brushes between the lips discontinued. However, such a regulation was difficult to enforce, and it was not until the advent of plastic adhesives with organic solvents of disagreeable taste and odor that this practice was entirely eliminated.

Although it is now well established that the practice of pointing the brushes with the lips was the predominant cause of the injury suffered by these workers, there are alive today, in apparent good health, several workers who used this method of pointing brushes for several years. This fact is mentioned to show that parts of the confusion in arriving at a solution of the problem arose from individual differences in the workers. Those who survived apparently developed a method of pointing the brushes that did not result in ingestion of appreciable amounts of the paint; others were more careless in this respect.

2. Radioactive Nature of Radium

Radium is always accompanied by its decay products in amounts dependent on a number of conditions. The properties of a sample of radium will be more readily understood by reference to Figure 7, which shows the genetic relationships in the radium family. We see that the immediate product of radium is a gas, radon, which decays to half-value every 4 days. This transformation is accompanied by the emission of an alpha particle for each atom transferred. By emission of another