is concerned no information is available, or will become available within present generations, to determine what intensities can be tolerated over a life span without producing an unbearable change in the mutation rate. Such observations are complicated by the fact that most mutations are recessive. Consequently, individuals who escape exhibiting any genetic effects of radiation in their immediate offspring may still be responsible for undesirable hereditary changes in later generations. This arises from the fact that the recessive nature of mutations is such that they ordinarily will not appear in the first succeeding generation. Therefore, the production of normal offspring by individuals exposed to radiation is no proof that genetic injury has not occurred.

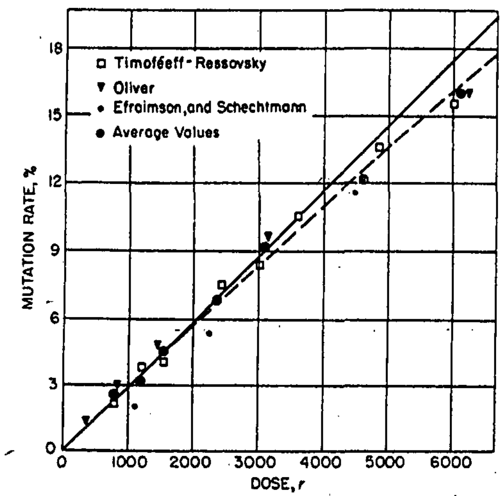

Figure 2. The solid line reveals the direct proportionality of rates of sex-associated mutations in *D. melanogaster* to dose of x-rays. The effect of the saturation curve on the direct proportionality is indicated by the dotted line. The observed points are by different authors as listed.

A certain low mutation rate is normally present in our population. In fact, this is one of the important factors that control the increase or decrease of population. These mutant genes must be eliminated from the population and are, on the average over suitably long periods, at a rate equal to that at which they are produced. The only mode of elimination is by a genetic death. Therefore, any marked increase in this mutation rate induced by exposure of the population to radiation could ultimately exterminate the whole population.

The reason for this can be made clearer from arguments recently outlined by Müller.[3] The most significant fact in a discussion of the effect of mutant genes

[3] H. J. Müller, *Acta Radiol.*, **41**, 5 (1954).

is that each of these received by an offspring will, on the average, cause a "genetic death" of one descendant. A genetic death may be defined as a death of an individual from genetic causes before reproduction, or a failure to reproduce. It does not need to be a "lethal" gene in the technical sense that it may cause so gross an abnormality as to kill every individual before maturity. Most mutant genes cause such a relatively small impairment in the individuals who carry them that ordinarily it would escape observation. However long the effect may be postponed, the genetic death is inevitable as the only way of eliminating this gene from the population.

Most mutant genes are recessive, a few completely so, and if transmitted by only one parent are about one-twentieth to one-thirtieth as effective as when transmitted by both, as deduced from studies on the fruit fly. In spite of the small damage caused in each individual, when summed up over many generations that may occur before elimination of the genes, the damage becomes significant. This situation means that every person is carrying a fairly large number of mutant genes, which are a biological handicap whose effects must be overcome to some extent by improved environmental conditions, and which will ultimately cause genetic death. In fact, the general fitness of an individual, apart from externally produced maladies and the like, may be said to depend directly on the combined action of the mutant genes he carries. The argument that a single mutant gene produces a relatively small, or entirely negligible, effect must be scrutinized carefully. The smaller the damage, the greater the number of generations before elimination. Consequently the total contribution is very large. In fact, it is equal to that of a major "lethal" gene whose effect is almost immediate.

The over-all effects may be reduced by the possibility that a given genetic death is caused by the co-operation of several mutant genes and the presence of adverse environmental conditions. In any case a number of mutant genes will probably be eliminated by each genetic death. Whatever this ratio, there must be the corresponding number of genetic deaths to prevent a continual increase in the number of mutant genes to the point where the whole population is exterminated.

To assess the effect of mutations induced by artificially applied radiation on the population the spontaneous mutation rate must be considered. This is estimated in man at one per 50,000 gametes. It may also be assumed conservatively that there are 15,000 genes per set, which suggests that there are 0.3 mutation present in human gametes of spontaneous origin. In practical words, this means 3 out of every 10 germ cells or eggs would contain somewhere a mutation that had developed in the immediately preceding generation, in addition to all those inherited over many past generations. Combining paternal and maternal contributions, 6 mutant genes must be eliminated for every 10 individuals per generation to maintain equilibrium. Even when also taking into account that it may require three mutations to cause a genetic death, 2 out of every 10 persons in each generation must suffer a genetic death. A simple calculation