

A total of  $M$  cells are exposed to X-ray radiation. X-rays produce chromosome breakages in cells. For each individual cell  $i \in \{1, \dots, M\}$ , the number  $N_i$  of breakages has a Poisson distribution with parameter  $\lambda$  (the random variables  $N_i$  are independent). Each breakage has a probability  $q$  of healing perfectly, a probability  $p$  of healing with a mutation, and a probability  $r = 1 - p - q$  of not healing (the associated events are independent between breakages). If all the breakages of a cell are not healed perfectly or healed with a mutation then the cell dies.

- a) What is the probability that a given cell dies from the radiation?
- b) What is the probability that a given cell survives the radiation without any mutations?
- c) What is the probability that a given cell survives the radiation with at least one mutation?
- d) What is the average number of mutations per surviving cells?