Mutations can be caused by several different factors. As discussed, errors by DNA polymerase during replication can cause mutations. Mutations can also occur because the DNA is damaged in some way. Such mutations are classified as being induced or spontaneous. Induced mutations are those that result from exposure to chemicals, UV rays, x-rays, or some other environmental agent. Spontaneous mutations occur without any exposure to any environmental agent; they are a result of natural reactions taking place within the body.

Mutations in repair genes have been known to cause cancer. Many mutated repair genes have been implicated in certain forms of pancreatic cancer, colon cancer, and colorectal cancer. Mutations can affect either somatic cells or germline cells.

Mutations can affect either somatic cells or germline cells. Recall that human somatic cells contain 46 chromosomes and these cells do not lead to the formation of gametes. Most cells that make up the human body are somatic cells. If mutations accumulate in a somatic cell, they may lead to problems such as the uncontrolled cell division observed in cancer. Somatic cell mutations can be extremely dangerous to the individual organism, but are not passed on to their offspring, therefore they are not heritable.

Germline cells, also called gametes, have half the number of chromosomes compared to a somatic cell. If a mutation takes place in germline cells, the mutation will be passed on to the next generation, and therefore is considered a heritable mutation. Hemophilia, a condition that effects an individual's ability to form blood clotting proteins, is an example of a germline mutation.

Check your knowledge

A mutation occurs in the leaf of a plant. Will the offspring of the plant be affected?

A mutation occurs in the ovary and eggs of a plant. Will the offspring of the plant be affected?

Answers: No, the leaf is a made of somatic cells that will not be passed on to the next generation. It is not heritable. The eggs, on the other hand, are gametes and germline cells. These will be heritable.

Section Summary

DNA replicates by a semi-conservative method in which each of the two "old" parental DNA strands act as templates for the two "new" complement DNA strands. After replication, each DNA helix has one parental or "old" strand, and one "new" complement strand.

Replication in eukaryotes starts at multiple origins of replication, while replication in prokaryotes starts from a single origin of replication. The DNA is opened with enzymes including an enzyme called helicase. This forms replication forks. RNA primase synthesizes an RNA primer to initiate DNA synthesis by DNA polymerase. DNA polymerase can add nucleotides in only one direction, the 5' to 3' direction. One strand is synthesized continuously in the direction of the replication fork; this is called the leading strand. The other strand is synthesized in a direction away from the replication fork, in short stretches of DNA known as Okazaki fragments. This strand is known as the lagging strand. Once replication is completed, the RNA primers are replaced by DNA nucleotides and the DNA fragments are joined together with DNA ligase.

The ends of eukaryotic chromosomes pose a problem, as DNA polymerase is unable to extend them without a primer. Telomerase, an enzyme with an inbuilt RNA primer, extends the ends by copying the RNA primer and extending the "lagging" end of the chromosome. DNA polymerase can then extend the DNA using the RNA primer. In this way, the ends of the chromosomes are protected. Cells have mechanisms for repairing DNA when it becomes damaged or errors are made in replication. These mechanisms include mismatch repair to replace nucleotides that are paired with a non-complementary base and nucleotide excision repair, which removes bases that are damaged such as thymine dimers. Most mistakes are caught and corrected; however, if they are not, they may result in a mutation. A mutation is defined as a permanent change in the DNA sequence. Changes in the DNA sequence can have effects on the protein products, which can be either beneficial or detrimental.

Exercises

1. DNA replicates by which of the following models?
    a. conservative
    b. semiconservative
    c. dispersive
    d. none of the above
2. The initial mechanism for repairing nucleotide errors in DNA is _____.
    a. mismatch repair
    b. DNA polymerase proofreading
    c. nucleotide excision repair
    d. thymine dimers
3. How do the linear chromosomes in eukaryotes ensure that its ends are replicated completely?
4. Mutations can be either beneficial or detrimental.
    a. TRUE
    b. FALSE

Answers

1. (b)
2. (b)
3. Telomerase has an inbuilt RNA template that extends the 3' end, so a primer is synthesized and extended. Thus, the ends are protected.
4. (a)

Glossary

DNA ligase: the enzyme that catalyzes the joining of DNA fragments together

DNA polymerase: an enzyme that synthesizes a new strand of DNA complementary to a template strand

helicase: an enzyme that helps to open up the DNA helix during DNA replication by breaking the hydrogen bonds

lagging strand: during replication of the 3' to 5' strand, the strand that is replicated in short fragments and away from the replication fork

leading strand: the strand that is synthesized continuously in the 5' to 3' direction that is synthesized in the direction of the replication fork

mutation: a permanent variation in the nucleotide sequence of a genome

Okazaki fragments: the DNA fragments that are synthesized in short stretches on the lagging strand

point mutation: occur when a single nucleotide is permanently changed in the DNA sequence

RNA primase: an enzyme that can base pair with the DNA and add a short stretch of RNA nucleotides called a primer. The primer is required to initiate DNA replication

RNA primer: short sequence of RNA nucleotides which DNA polymerase can add DNA nucleotides to

replication fork: the Y-shaped structure formed during the initiation of replication

semiconservative replication: the method used to replicate DNA in which the double-stranded molecule is separated and each strand acts as a template for a new strand to be synthesized, so the resulting DNA molecules are composed of one new strand of nucleotides and one old strand of nucleotides

telomerase: an enzyme that contains a catalytic part and an inbuilt RNA template; it functions to maintain telomeres at chromosome ends

telomere: the DNA at the end of linear chromosomes

Footnotes

1 Mariella Jaskelioff, et al., "Telomerase reactivation reverses tissue degeneration in aged telomerase-deficient mice," *Nature*, 469 (2011):102–7.