1. Crossing over in meiosis I is required for homologous chromosomes to properly align during metaphase and segregate during the first cell division.

(a)

(i) **Describe** the function of S phase of interphase.

Some regions of a chromosome called hotspots display a higher frequency of crossing over than other regions do. Crossing over is suppressed in chromosomal regions near the centromeres. The centromere region of a duplicated chromosome includes a collection of proteins that form a structure called the kinetochore. Scientists hypothesized that one or more of these kinetochore proteins are responsible for suppressing crossing over around the centromere.

To investigate their hypothesis, scientists modified chromosome 8 in yeast such that, in each cell, one chromosome from the pair of homologous chromosome 8s contained the gene encoding red fluorescent protein (RFP), while the other chromosome from the pair contained the gene encoding green fluorescent protein (GFP). Cells expressing RFP emit (give off) red light, and cells expressing GFP emit green light. Models of the modified chromosome 8 both before and after crossing over are shown in Figure 1.

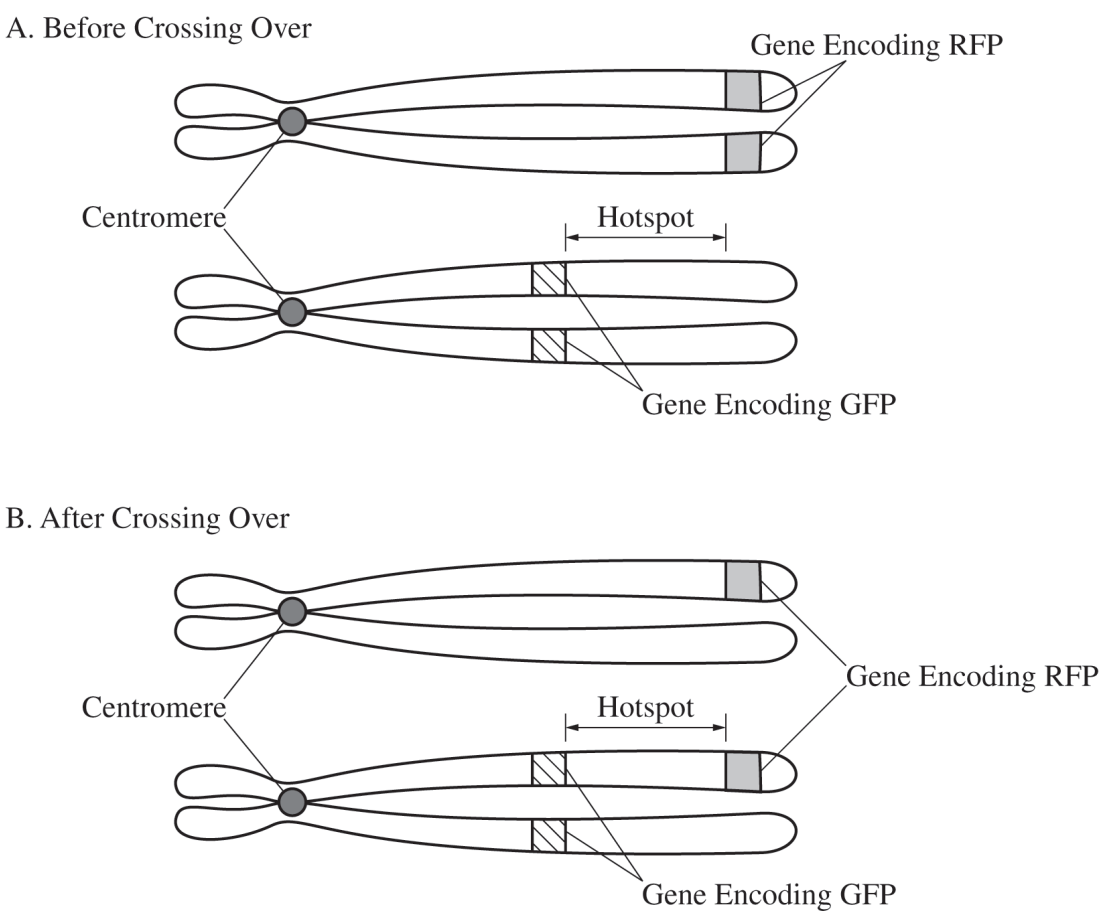

Figure 1. Models of modified chromosome 8 used in the experiment (A) before and (B) after crossing over occurs at the hotspot

(ii) **Explain** why some haploid cells formed after meiosis in this experiment will have only one fluorescent marker.

The scientists then investigated whether attaching individual kinetochore proteins to a specific DNA sequence present in a known crossing-over hotspot on chromosome 8 affected the frequency of crossing over at this location. In their first experiment, they examined three groups of yeast cells containing the modified chromosome 8. Group 1 contained no kinetochore proteins attached to the hotspot, group 2 contained the kinetochore protein CTF attached to the hotspot, and group 3 contained the kinetochore protein IML attached to the hotspot. For each group, the scientists determined the frequency of crossing over between the RFP and GFP genes. To determine the frequency, the scientists added the number of cells emitting both red and green light to the number of cells that emitted no light and divided by the total number of cells (Figure 2).

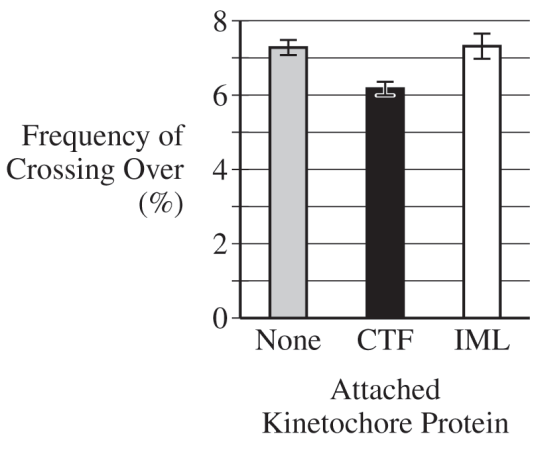

Figure 2. The frequency of crossing over in a hotspot on yeast chromosome 8 for cell groups treated with different kinetochore proteins. Error bars represent $\pm 2SE_{\bar{x}}$.

(b)

(i) **Identify** the control group for the scientists' first experiment, shown in Figure 2.

(ii) In a follow-up experiment, the scientists created a modified version of CTF in which the DNA-binding portion had been removed. They compared the frequency of crossing over in yeast cells in the presence and absence of unmodified CTF with that in yeast cells in the presence and absence of the modified CTF protein (data not shown). In the follow-up experiment, **justify** why the scientists used a modified CTF protein that is unable to bind to DNA as a control.

(iii) **Identify** the independent variable in the follow-up experiment.

(c) Based on Figure 2, **describe** the effect on the frequency of crossing over when CTF is attached to the chromosome 8 hotspot compared with the effect when IML is attached to the hotspot.

(d)

(i) **Predict** the effect on the number of copies of chromosome 8 likely to be present in the resulting daughter cells when CTF is attached to the hotspot.

(ii) Provide reasoning to **justify** your prediction.

(iii) **Explain** how the presence of hotspots (Figure 1) could increase the likelihood that a population will survive in the presence of selective pressures.

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If there are multiple parts to this question, write the part letter with your response.