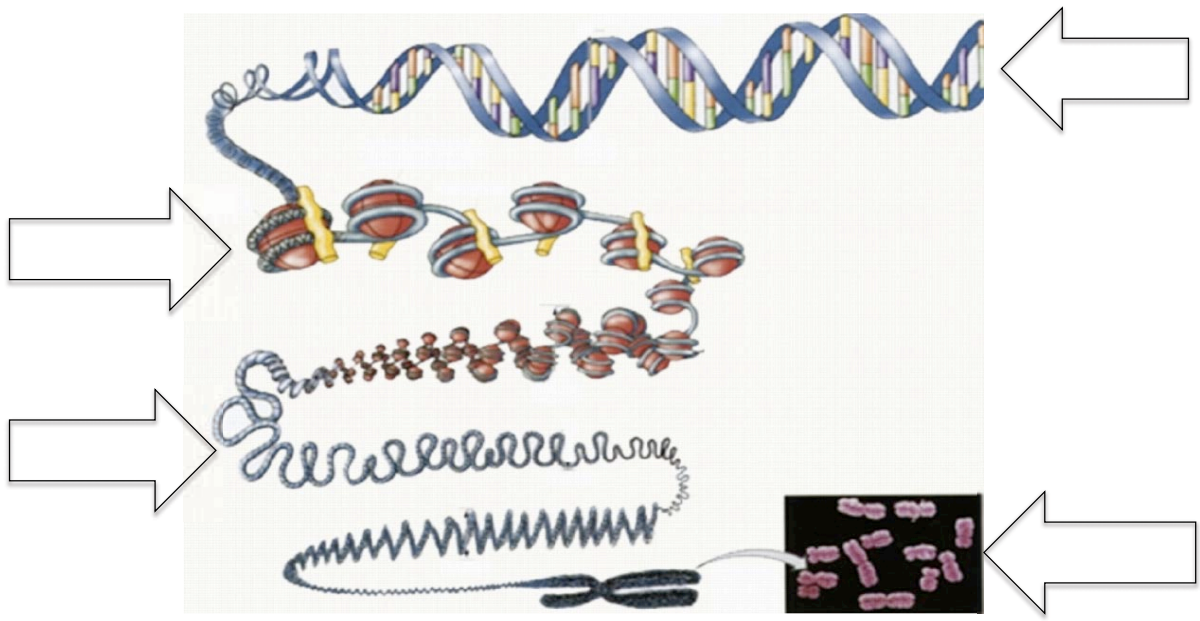
Name: _____ Date: _____

Part A: simple questions on basic biology (fill in or cross the answer, 1 point for each correct answer)

1. Assign names to the parts shown in this figure (chromatin; chromosome; DNA double strand; nucleosome)



2. The nucleosomes are made of

A. proteins
B. RNA
C. DNA
D. a DNA/protein complex
E. phospholipids

Part B: further simple questions on basic biology (provide a short written answer, up to 2 points for each correct answer)

3. What is the difference between germ cells and somatic cells?

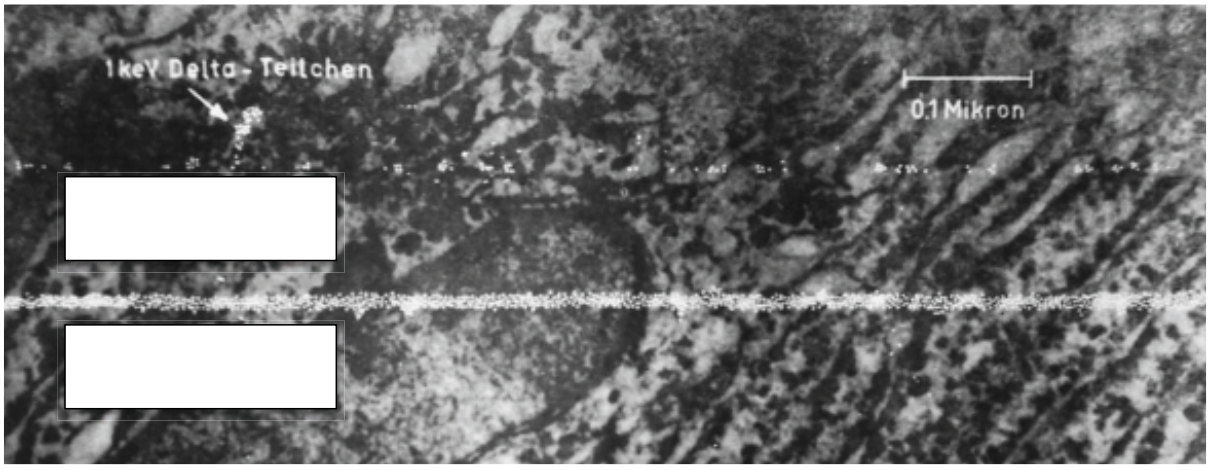
4. What kind of disease is Ataxia-Telangiectasia?

5. What is an intron?

6. What is a mitochondrion?

Part C: basic questions on the interaction of radiation with cells (either mark the correct answer or provide a short written answer, up to 2 points for each correct answer)

7. The following figure shows a simulation of the ionization produced by two proton beams of different energy (1 MeV and 500 keV) superposed on a the photograph of a human cell. The tracks are marked by white dots (ionizations), and one of them also emits a delta ray (scattered electron)



A. identify the proton tracks by writing the correct energy below each track
B. an organelle is visible on the lower left: can you identify it?

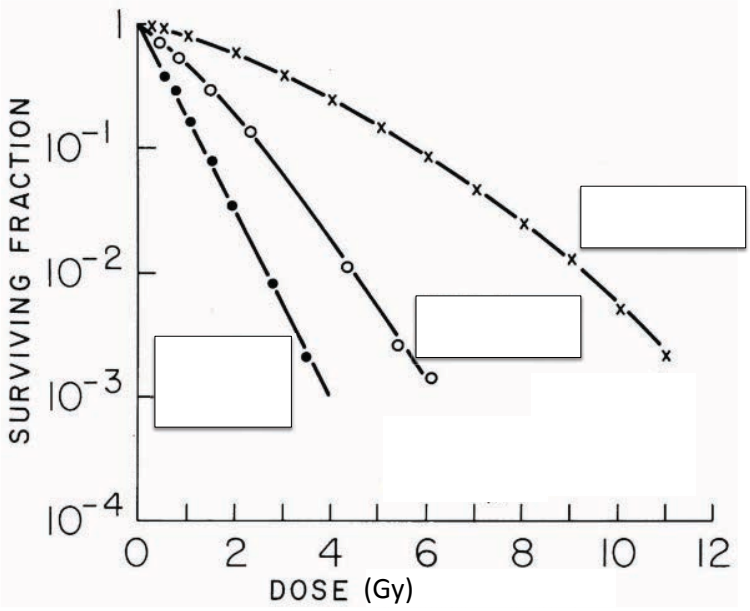
8. How is the G value defined?

9. How does the mutation rate in mouse compare with the mutation rate in humans? Are the results of tests of mutagens on mice reliable when used to assess the danger to humans?

10. What does the enzyme *catalase* do?

11. List at least three mutagens

12. Consider the following figure that shows three different survival curves. The curves show the surviving fraction of cultured cells of human origin exposed to 250-kVp x-rays, 15-MeV neutrons, and 4-MeV α-particles, and they display the effect of radiation with different LET. Identify each curve with the corresponding radiation.



Part D: this part contains discussions on a radiobiology argument highly relevant to radiotheraphy. Provide answers as requested in the text. (up to 2 points for each correct answer)

13. Write the Biologically Effective Dose (BED) as a function $BED(D,N)$ of the total dose *D* and of the number of fractions *N*

14. Consider the BED modified with the inclusion of total treatment time *T* in a fractionated radiotherapy

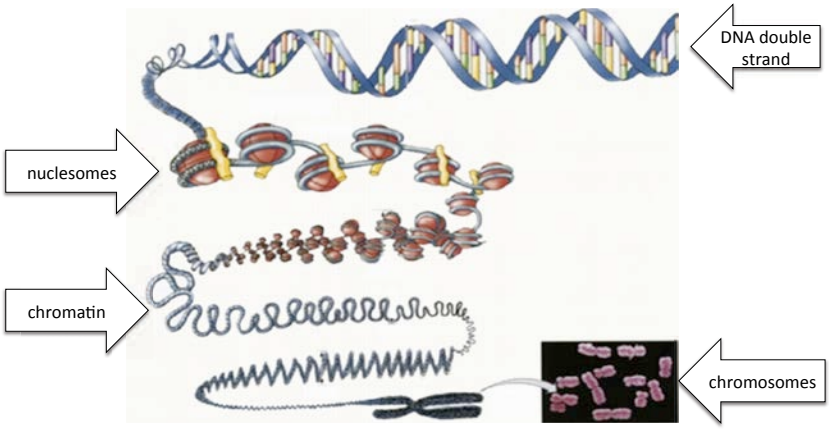
$$BED(D,N,T) = BED(D,N) - \frac{T - Tk}{\alpha Tp/\ln 2}$$

where *N* is the number of fractions, *Tk* is the kickoff time for tumor cell repopulation and *Tp* is the tumor population doubling time. Clearly, because of the time-dependent term, the longer we wait, and the less effective the treatment is;

- let Δt be the time between fractions and write the total time as a function of *N* and Δt
- use the previous result to rewrite the expression $BED(D,N,T)$ as a function $BED(D,N,\Delta T)$
- we may be tempted to optimize this result, so as to maximize the BED delivered to the tumor: find the value of *N* that maximizes the BED without performing any calculation (but motivate your answer)
- what is missing from this attempt to optimize the dose? We optimize by delivering a dose as high as possible, but at the same time we must put constraints on the maximum dose: name at least one constraint.

Answers

Part A



1.

2. D

Part B

3. Germ cells are either a sperm or an egg, all other human cells are called soma)c cells.

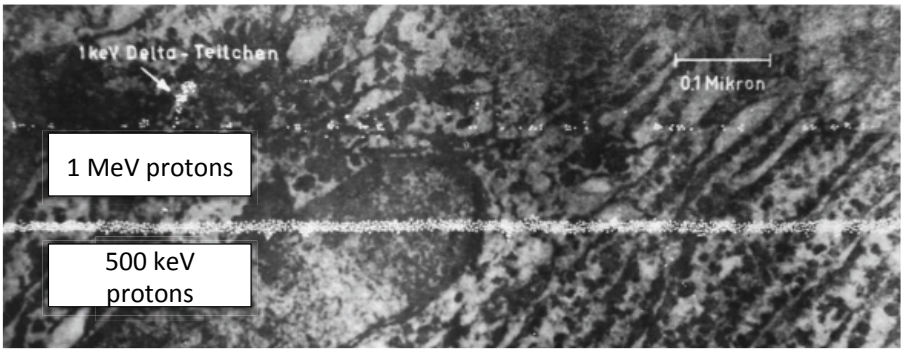
4. It is a genetic disease where the ATM gene is broken, and this impairs the DNA-repair pathways

5. An intron is a noncoding part of DNA

6. A mitochondrion is an organelle which synthesizes ATP

Part C

7.



The organelle is a mitochondrion

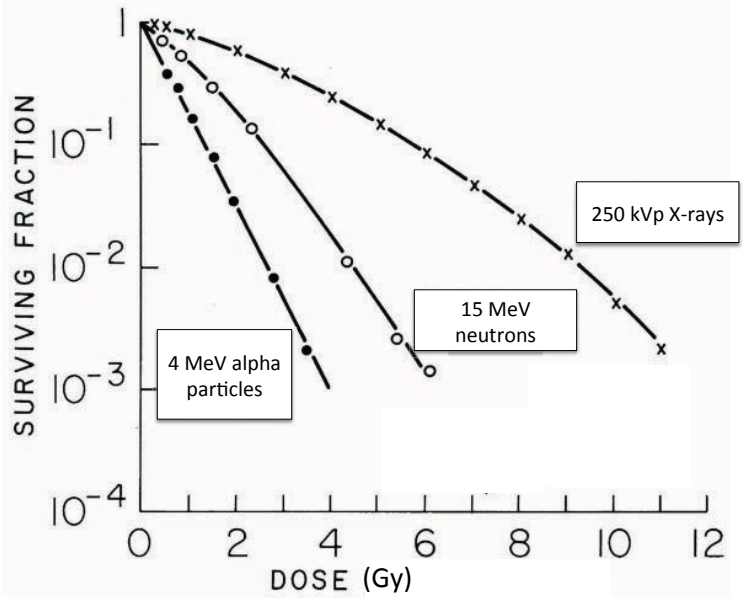
8. The G value is the number of a given species produced per 100 eV of energy loss by the original charged particle and its secondaries, on the average, when it stops in water.

9. The mutation rate is higher in mice. This may make tests of mutagens unreliable when applied to humans.

10. Catalase transforms hydrogen peroxide into water.

11. Example: radiation, chemicals, viruses

12.



Part D

13. $BED(D,N) = D\left(1+\frac{D/N}{\alpha/\beta}\right)$

14. The total time is $T = (N-1)\Delta t$. This means that

$$BED(D,N,T) = BED(D,N) - \frac{T - Tk}{\alpha Tp/\ln 2}$$
$$= D\left(1+\frac{D/N}{\alpha/\beta}\right) - \frac{(N-1)\Delta t - Tk}{\alpha Tp/\ln 2}$$

This expression has two terms: the first is positive and becomes larger for smaller *N*, the second becomes more negative for larger *N*. This means that the BED is largest for *N*=1.

This result is mathematically correct, but it is not acceptable in practice. Indeed the total dose in a regular treatment is of the order of several tens of Gy's, and this means that damage to healthy tissues in a non-fractionated treatment could be excessive. Thus, to optimize we should include at least one term that takes into account the normal tissue complication probability (NTCP).