

Chapter 14: Growth and post-embryonic development

Overview: When the non-scientist thinks of development, he or she is probably thinking about post-embryonic growth. As you now know, the study of development focuses largely on earlier events and stages, many occurring in the first few days after fertilization. Nonetheless, growth is also a part of the normal developmental program; even aging and death can be considered developmental events. Growth is controlled by genetic programs intrinsic to a cell's development, by growth factors secreted by other tissues or organs, and by the nutritional adequacy of the environment. Of special interest in the study of growth and its control is the relationship of growth control to cancer; cancer is a disease best characterized by loss of growth control, and the study of cancer has taught us much about the mechanisms which control growth and cell division in normal cells.

Study tip: As you study this chapter, be sure to integrate this information into your knowledge of embryonic development from previous chapters. Try to view the continuum of development, growth, and aging, rather than segregating this information away as a separate topic.

Keywords: Briefly compare and contrast the following pairs of terms. Check your answer by using the glossary and the text.

growth / morphogenesis
morphogen / growth factor
diaphysis / epiphysis
oncogene / tumor suppressor gene
embryonic stem cell / teratocarcinoma
molting / metamorphosis
juvenile hormone / ecdysone
polytene chromosome bands / polytene chromosome puffs

Factual recall questions:

- Growth involves
 - increases in cell size
 - increases in cell number
 - increase in the volume between cells
 - cell death
 - all of the above
- Cyclins act by forming complexes with
 - G1 phase
 - kinases
 - growth factors
 - DNA
 - DNA polymerase
- Growth hormone is produced in the
 - liver
 - pituitary
 - hypothalamus
 - spleen
 - thymus
- Adult human bone
 - grows only at the extreme ends
 - grows only in the center
 - grows only at the growth plate near the end
 - grows at all three regions
 - does not grow at all after maturity is reached
- Cells are most likely to develop into cancer if
 - they are exposed to growth factors
 - they are embryonic
 - they divide frequently

- (d) they are destined to form bone
- (e) they contain proto-oncogenes

6. Molting and metamorphosis in insects are triggered by
- (a) ecdysone
 - (b) juvenile hormone
 - (c) auxin
 - (d) cytokinin
 - (e) growth hormone

Concept questions:

1. Use limb length in the adult as an example to describe the importance of growth and growth control to the final shape and form of the adult.
2. Without looking at Figure 14.2, draw a schematic of a eukaryotic cell cycle and define each of the stages. Which stages of the cycle are modified when rapid divisions occur in embryos? Which stages are modified in adults, where most cell types rarely if ever undergo cell division? Where is the key decision point, with regard to the initiation of a new cell cycle?
3. What is the role of growth factors in growth control? Return to previous chapters and use muscle and neurons as examples of how growth factors influence development through their effect on differentiation and survival.
4. Describe the role of cyclins in controlling the cell cycle. What is the molecular basis for their variation in concentration during the cell cycle?
5. How do the cell division cycles change in the *Drosophila* embryo at cycle 14, the mid-blastula transition? In what way does control of these early divisions in the embryo differ from the control of division in most cells, even in the imaginal discs?
6. Contrast the consequences of transplanting spleens versus thymus glands into a developing mouse embryo, with regard to intrinsic and systemic influences over growth. Which of these influences operates when a limb is grafted from a large species of salamander to a smaller species; describe the experimental result.
7. How is the size of a cell typically related to nuclear ploidy? How has this observation been exploited to study the regulation of growth control in the *Drosophila* wing imaginal disc?
8. Study Figure 14.8, then outline, without looking, the interactions that regulate the growth hormone production and its effects on cell multiplication.
9. Describe the hormonal control of bone growth. What molecules are involved? Where do they come from, and where do they act? How does it occur that long bones on opposite sides of the body come to grow to the same length, despite a lack of direct communication between them?
10. Contrast oncogenes with tumor suppressor genes. What is their normal role in growth control? Which is dominant, and how does that influence their role in cancer? Why is the other type of gene considered to be recessive?
11. Using the *Rb* gene as an example, describe the role of tumor suppressor genes in normal growth control, and in the development of cancer.
12. What is the connection between stem cell populations and the propensity toward cancer in a given tissue? Consider skin, intestinal epithelium, and blood as examples: Where are their stem cells? What is their normal differentiation program? What molecular markers might cancers from these tissues express that would give clues as to their origin. In answering, ask yourself: would the tumor cells express the markers characteristic of the fully differentiated state? For example, could mature non-nucleated red blood cells be cancer cells?
13. How do ES cells illustrate the role of environment on cancer cells?
14. Describe an experiment that demonstrates the role of auxin in controlling growth in plants.
15. Refer to Figure 7.9. Indicate those areas where growth of the plant is due to cell division. In what areas is growth occurring by directed dilation?

16. When an insect such as *Drosophila* undergoes metamorphosis, what happens to the majority of the larval tissue? Are any larval tissues maintained to appear in the adult? Where do most of the adult tissues come from?
17. Outline the sequence of cues which trigger metamorphosis in butterflies. Include the corpus allatum, the prothoracic gland, PTTH, juvenile hormone, and ecdysone. Conclude by describing the effect of ecdysone on the cell, that is, how does ecdysone control cellular behavior?
18. Outline the sequence of events involved in frog metamorphosis, including the organs and hormones involved. How does thyroxine control cellular behavior?
19. Define senescence.
20. What do the differing life spans of different animals tell us about the underlying cause of aging and senescence? What is the evolutionary logic behind senescence and death? What is this theory called?
21. What is the evidence from *C. elegans* that life span is under genetic control? How does the nervous system influence this pathway?
22. What is a "reactive oxygen radical"? Where do they come from? How is it thought that they affect the aging process? How does Werner's syndrome support this hypothesis?
23. In what way do fibroblasts growing in culture mimic the normal senescence program?
24. What are telomeres? What is their relationship to aging and senescence? Cancer cells often have activated the gene for telomerase, an enzyme that maintains telomeres; how might this affect their ability to divide indefinitely in culture? In contrast, most normal adult human cells have turned off telomerase, and drugs that would reactivate telomerase have been proposed as treatments for aging. Argue for and against this therapy.