Chapter 14

Controls Over Genes
Gene Expression in Eukaryotic Cells

• **Gene expression**
  – Multistep process by which a cell converts gene information into a gene product

• Which genes a cell uses depends on:
  – Type of organism and type of cell
  – Factors inside and outside the cell
  – Organism’s stage of development
Gene Controls in Multicelld Eukaryotes

- **Gene control**
  - The basis of embryonic development

- All cells of an embryo share the same genes
  - Different lineages use different subsets of them during development
Cell Differentiation

• Cell differentiation, the process by which cells becomes
  – Different cell lineages become unique in composition, structure, and function

• Differentiated cells give rise to specialized tissues and organs
Controls Over Eukaryotic Gene Expression

**a) Transcription**
Control over chemical modifications of DNA and histones affect physical access to genes. Chromosomes may be copied many times in cells that make a lot of protein.

**b) RNA Processing**
New, unmodified mRNA cannot leave the nucleus, so controls over mRNA processing affect the timing of transcription. Controls over alternative splicing influence the final form of the protein.

**c) RNA Transport**
RNA cannot pass through a nuclear pore unless it is bound to certain proteins. Controls over transport protein binding affect whether a transcript will be delivered to the proper area of the cell.

**d) Translation**
Controls over an mRNA’s stability influence how long it gets translated. Proteins that attach to ribosomes or initiation factors can inhibit translation. Double-stranded RNA triggers degradation of complementary mRNAs by RNA interference.

**e) Protein Processing**
A new protein molecule may become activated or disabled by enzyme-mediated modifications, such as phosphorylation or cleavage. Controls over these enzymes influence many other cell activities.
Controls of Transcription

• Several controls affect attachment of RNA polymerase to DNA
  – Promoters
  – Enhancers
  – Activator
  – Repressor
  – Transcription factors
Controls of Transcription

DNA
wound around histone spool
unwound DNA region
Key Concepts:

OVERVIEW OF THE CONTROLS

- Control mechanisms govern when, how, and to what extent a cell’s genes are expressed
  - They alter gene expression in response to changing conditions inside and outside the cell

- Diverse controls govern every step between gene transcription and delivery of the final gene product to a targeted location
Key Concepts:

OVERVIEW OF THE CONTROLS (cont.)

• In multicelld species, master genes guide the stage-by-stage development of new individuals

• Selective gene expression results in cell differentiation
  – Different cell lineages become specialized in composition, structure, and function
X Chromosome Inactivation

• In female mammals, genes on one of two X chromosomes is active
  – Barr bodies (transcriptional control)
  – Balances gene expression between the sexes

• XIST gene is transcribed on one X chromosome
  – Gene’s RNA product shuts down the chromosome that transcribes it
  – Transcription of the XIST gene keeps the chromosome from transcribing other genes
Gene Control of Flower Formation

• Studies of mutations in Arabidopsis thaliana support ABC model for flower formation

• Three sets of master genes (A, B, C) guide cell differentiation in the whorls of a floral shoot
  – Sepals, petals, stamens, and carpels form
Gene Control of Flower Formation

**Gene Control of Flower Formation**

The pattern in which the floral identity genes A, B, and C are expressed affects differentiation of cells growing in whorls in the plant’s tips. Their gene products guide expression of other genes in cells of each whorl; a flower results.

Mutations in *Arabidopsis* floral identity genes result in mutant flowers. *Top left, right,* some mutations lead to flowers with no petals. *Bottom left,* B gene mutations lead to flowers with sepals instead of petals. *Bottom right,* C gene mutations lead to flowers with petals instead of sepals and carpels. Compare the normal flower in (a).
Key Concepts:

EXAMPLES FROM EUKARYOTES

- Orderly, localized expression of certain genes is the basis of the body plan of complex multicelled organisms

- In female mammals, most of the genes on one of the two X chromosomes are inactivated in every cell
Research: Gene Expression

• *Drosophila melanogaster*
  – Experimental mutations reveal controls over gene expression that govern embryonic development of all animals
Homeotic Genes

• Master genes (homeotic genes) are transcribed in different tissues at different times during embryo development

• Gene products affect expression of other master genes, which affect the expression of others, and so on (cascades)
Cascades of Gene Expression
**Key Concepts: CASE STUDY:**

**FRUIT FLY DEVELOPMENT**

- Drosophila research revealed how a complex body plan emerges

- All cells in a developing embryo inherit the same genes, but they selectively activate or suppress different fractions of those genes
Prokaryotic Gene Control

• Prokaryotic cells
  – Do not have great structural complexity
  – Do not undergo development

• Most gene controls reversibly adjust transcription rates in response to environmental conditions
  – Especially nutrient availability
Bacterial Lactose Operon

• An arrangement in which a single promoter and one or more operators control access to multiple genes is called an operon.

• Governs expression of three genes
  – Three products digest lactose

• Two operators flank the promoter
  – Binding sites for repressor that blocks transcription
**Negative Control of Lactose Operon**

**Lactose absent**

- **operator**
- **promoter**
- **operator**

**Gene 1**

- **Gene 2**
- **Gene 3**

- Repressor protein

**a** In the absence of lactose, a repressor binds to the two operators. Binding prevents RNA polymerase from attaching to the promoter, so transcription of the operon genes does not occur.

**Lactose present**

- lactose
- mRNA
- RNA polymerase

**b** When lactose is present, some is converted to a form that binds to the repressor. Binding alters the shape of the repressor such that it releases the operators. RNA polymerase can now attach to the promoter and transcribe the operon genes.
Key Concepts:

• Prokaryotic gene controls govern responses to short-term changes in nutrient availability and other aspects of the environment

• The main gene controls bring about fast adjustments in rates of transcription