Chapter 18

Regulation of Gene Expression

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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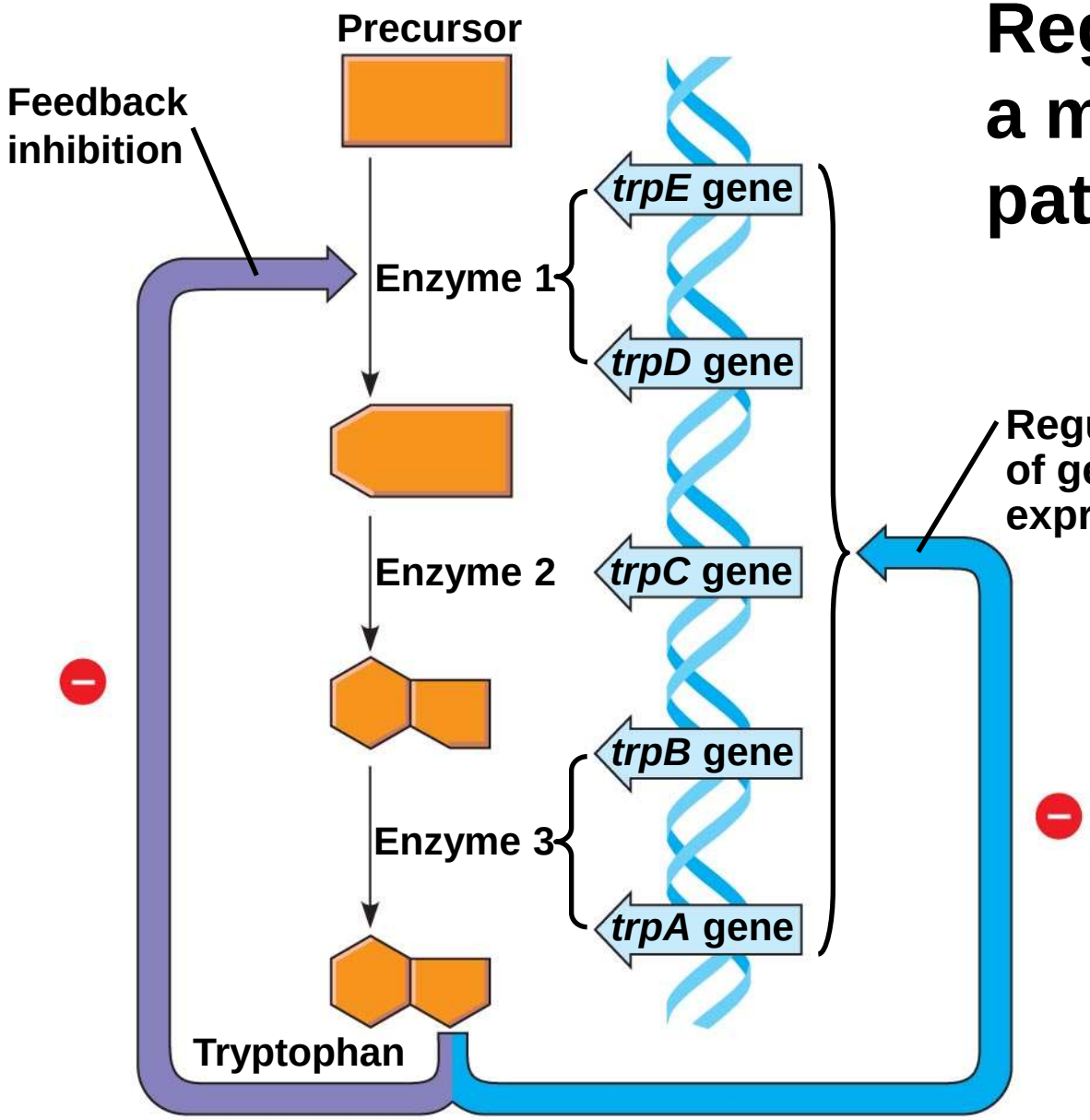
Overview: Conducting the Genetic Orchestra

- Prokaryotes and eukaryotes **alter gene expression in response to their changing environment**

Bacteria often respond to environmental change by regulating transcription

- Natural selection has favored bacteria that produce only the products **needed by that cell**
- A cell can regulate the production of enzymes by **feedback inhibition** or by **gene regulation**
- Gene expression in bacteria is controlled by the **operon model**

Regulation of a metabolic pathway

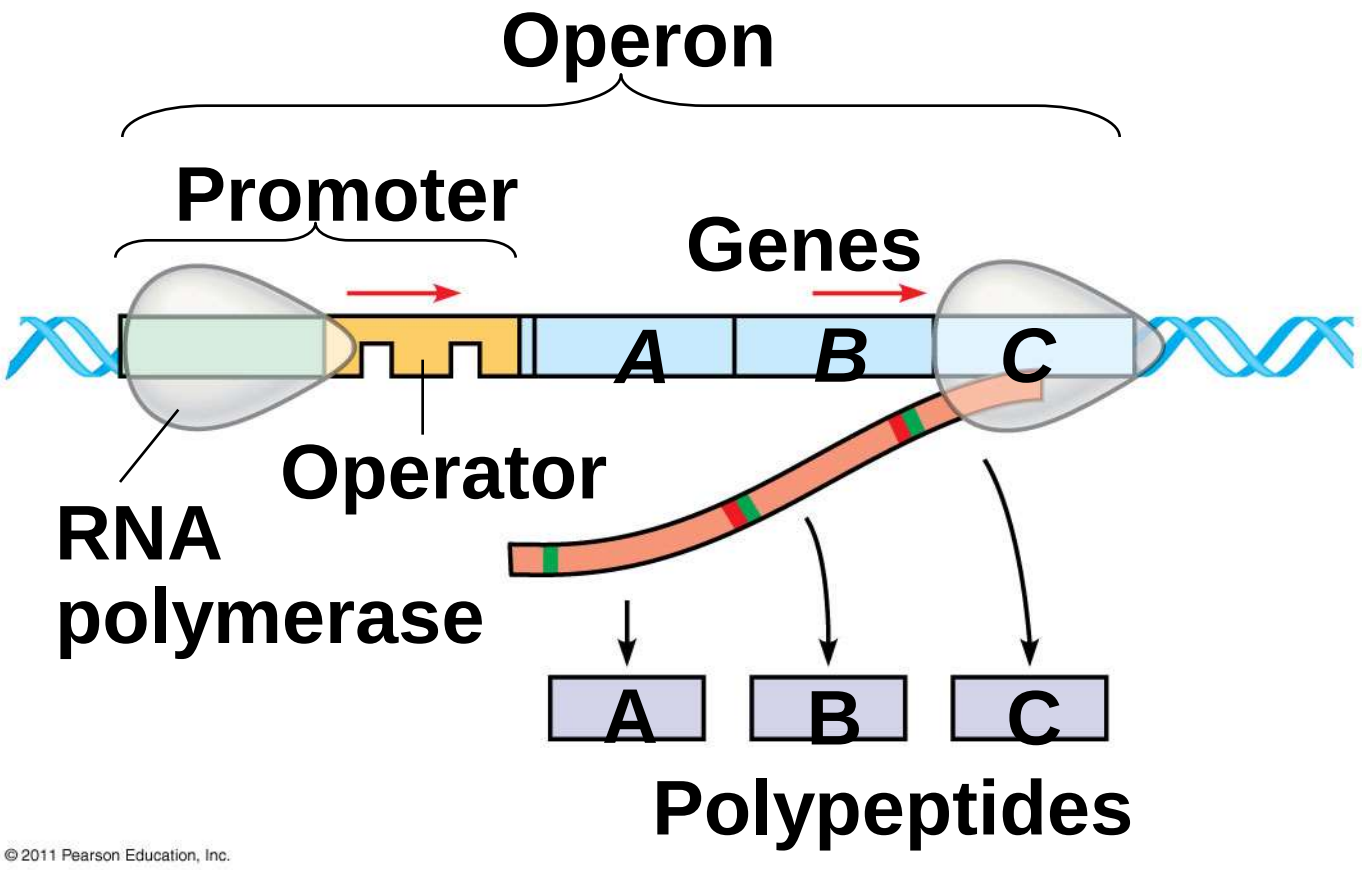


(a) Regulation of enzyme activity

(b) Regulation of enzyme production

Operons: The Basic Concept

- **A cluster of functionally related genes can be under coordinated control by a single on-off "switch"**
- The regulatory "switch" is a **segment of DNA** called an **operator** usually positioned within the promoter
- An **operon** is the **entire stretch of DNA that includes the operator, the promoter, and the genes that they control**



- The operon can be switched off by a protein **repressor**
- The repressor prevents **gene transcription**
- The repressor is the product of a separate **regulatory gene**

Repressible and Inducible Operons: Two Types of Negative Gene Regulation

- A **repressible operon** is one that is **usually on**; binding of a repressor to the operator shuts off transcription
- An **inducible operon** is one that is **usually off**; a molecule called an inducer inactivates the repressor and turns on transcription

EXAMPLE:

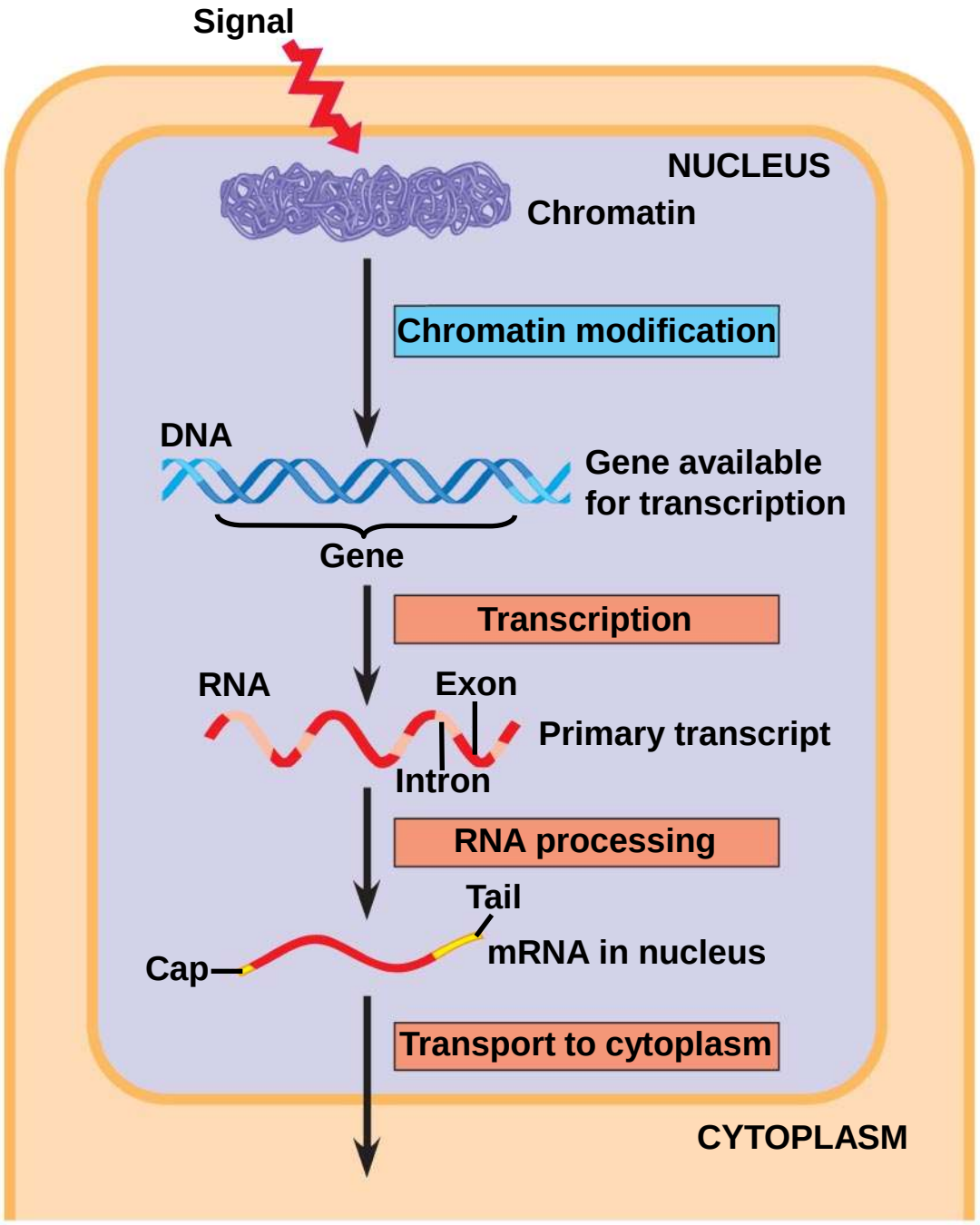
The ***lac* operon** is an inducible operon and contains genes that **code for enzymes used in the hydrolysis and metabolism of lactose**

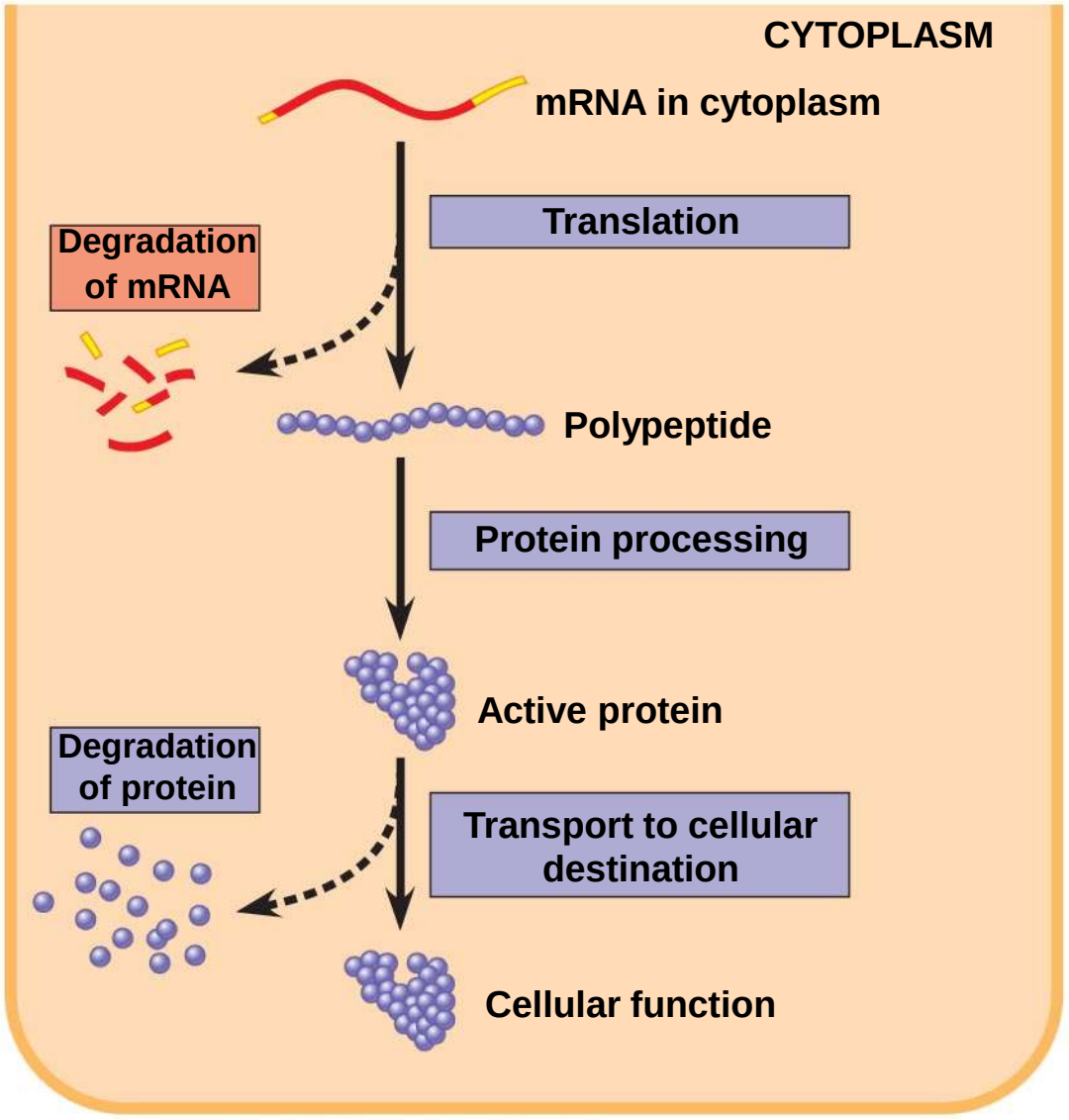
Eukaryotic gene expression can be regulated at any stage

- All organisms must regulate which genes are expressed **at any given time**
- In multicellular organisms gene expression is **essential for cell specialization**

Differential Gene Expression

- **Almost all the cells in an organism are genetically identical**
- Differences between cell types result from **differential gene expression**, the expression of different genes by cells with the same genome
- Errors in gene expression can lead to diseases including cancer
- Gene expression is regulated **at many stages**



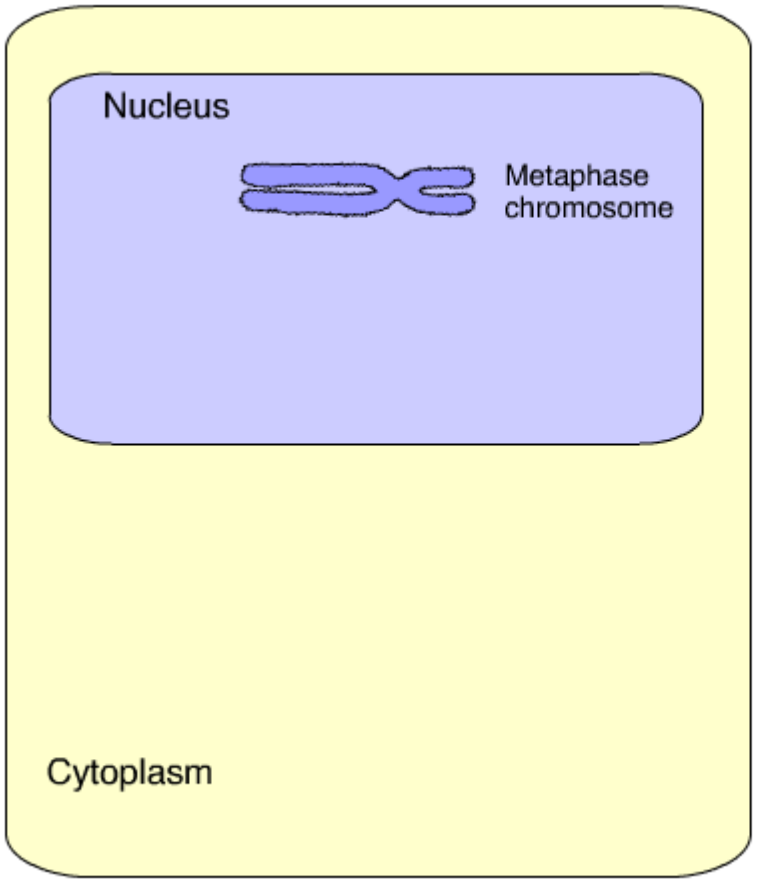


Regulation of Chromatin Structure

- Chemical modifications to histones and DNA of chromatin influence both **chromatin structure** and **gene expression**

Regulation of Transcription Initiation

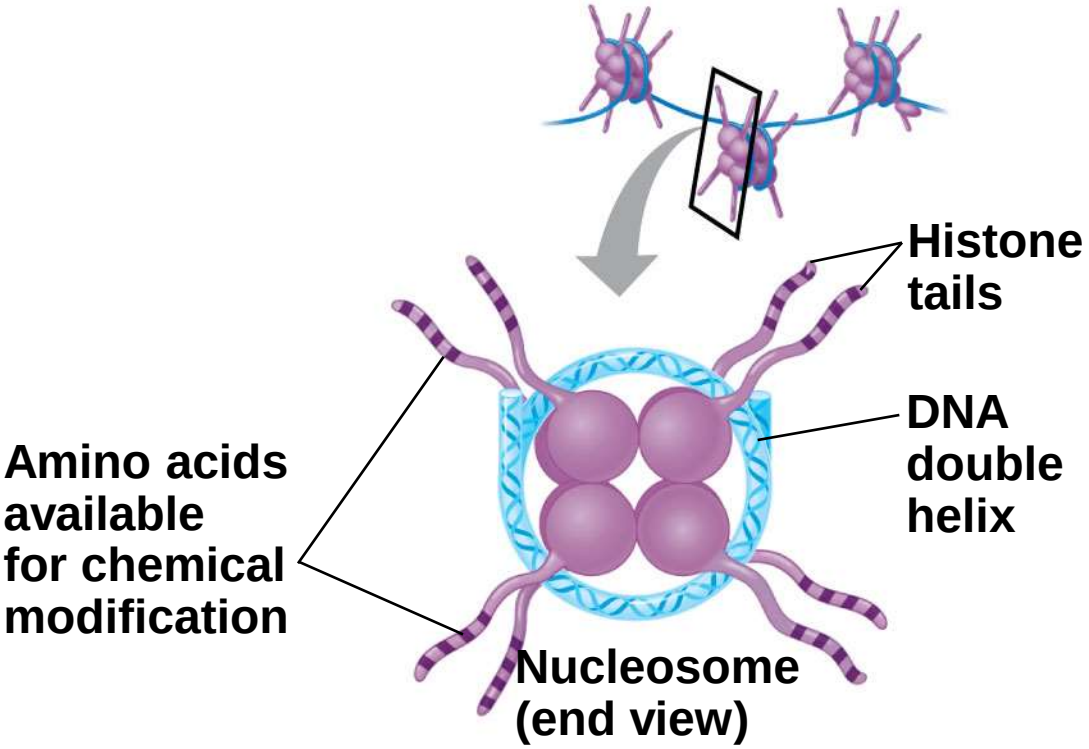
- Chromatin-modifying enzymes provide initial control of gene expression by **making a region of DNA either more or less able to bind the transcription machinery**



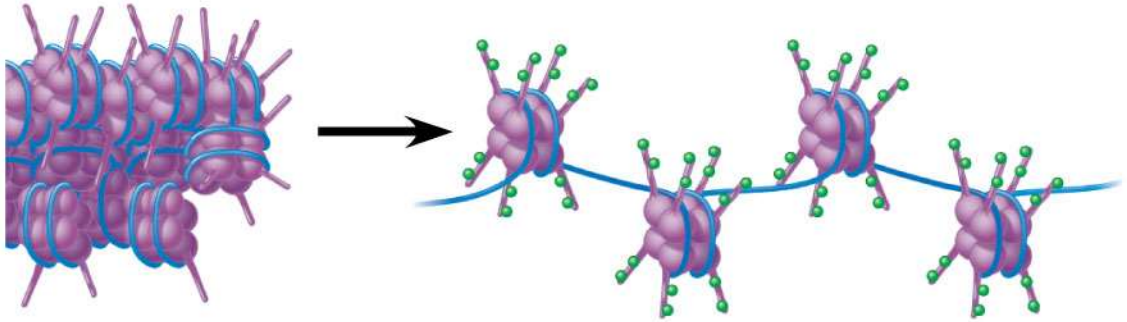
Animation: DNA Packing

Right-click slide / select “Play”

A simple model of histone tails and the effect of histone acetylation



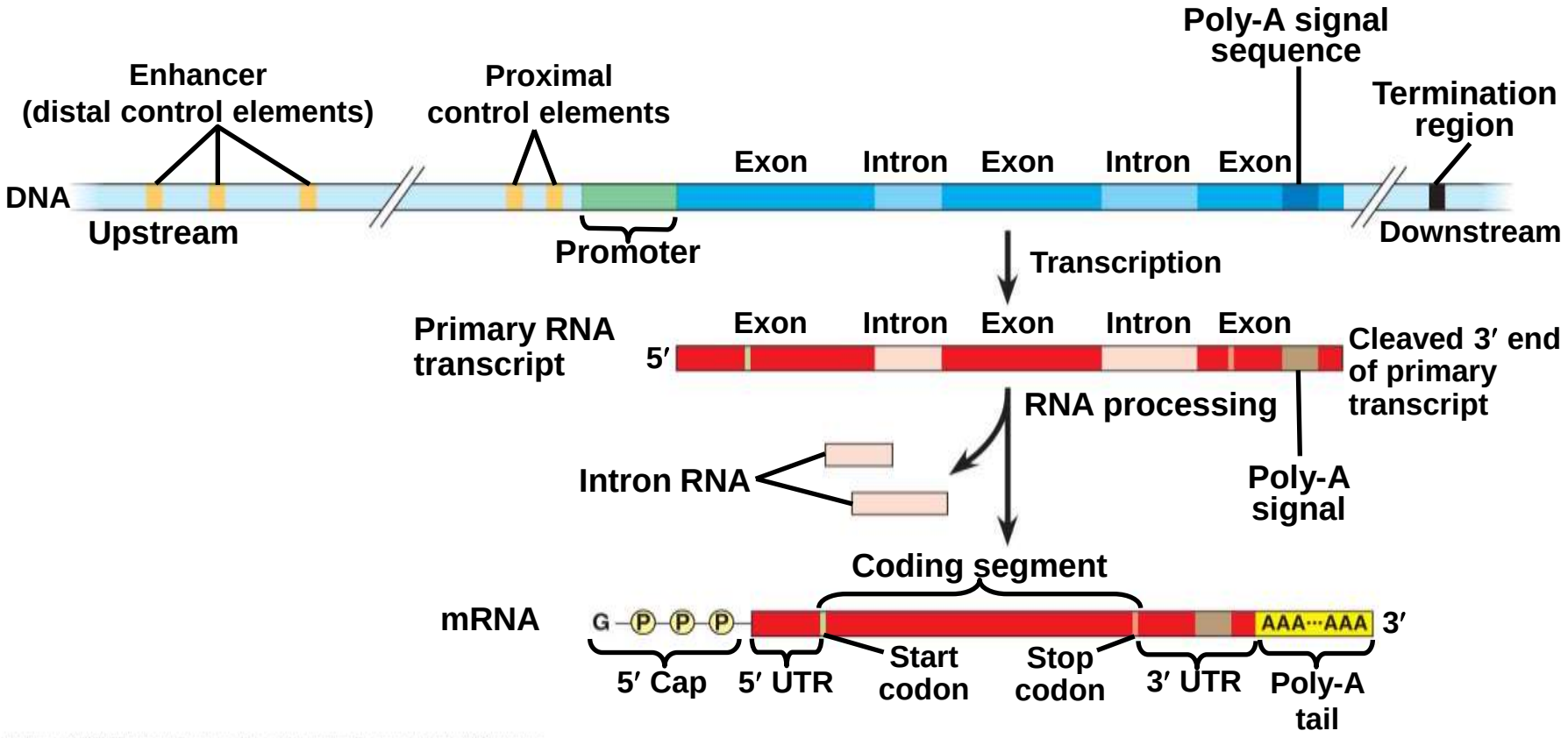
(a) Histone tails protrude outward from a nucleosome



Unacetylated histones Acetylated histones

(b) Acetylation of histone tails promotes loose chromatin structure that permits transcription

A eukaryotic gene and its transcript



Mechanisms of Post-Transcriptional Regulation

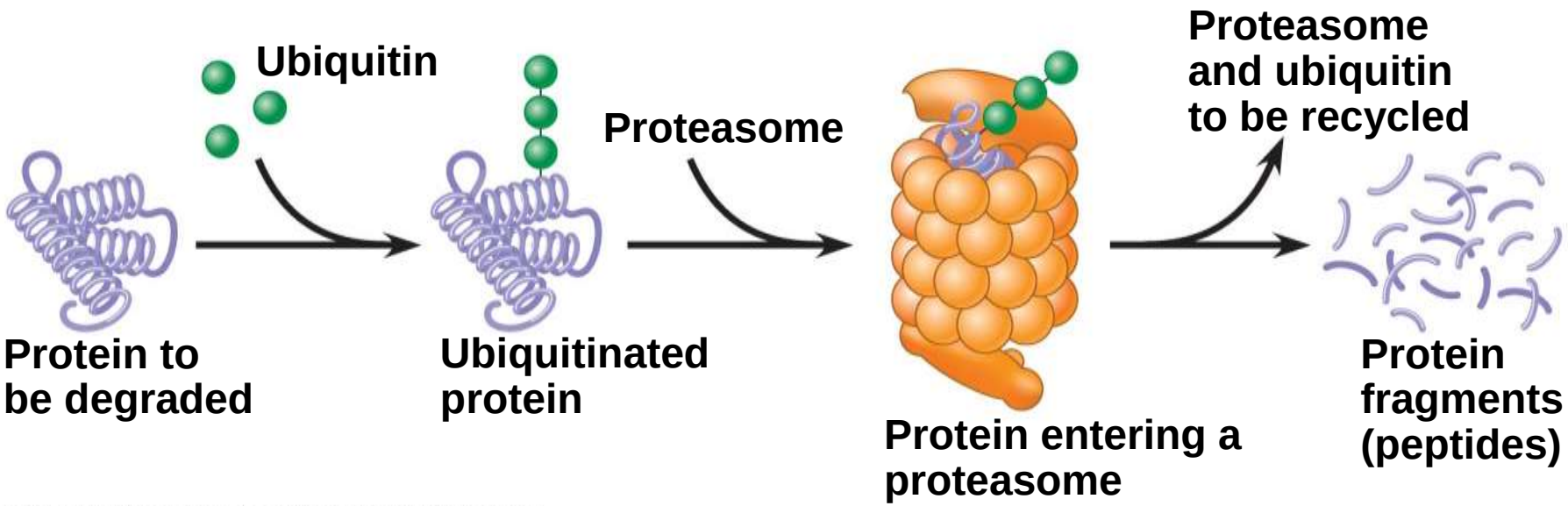
- **Transcription alone does not account for gene expression**
- Regulatory mechanisms can operate at various stages **after transcription**
- Such mechanisms allow a cell **to fine-tune gene expression rapidly in response to environmental changes**

Initiation of Translation

- The initiation of translation of selected mRNAs can be **blocked by regulatory proteins**
- Alternatively, translation of all mRNAs in a cell may be **regulated simultaneously**
- For example, translation can be simultaneously activated in an egg following fertilization

Protein Processing and Degradation

- After translation, various types of protein processing, including cleavage and the addition of chemical groups, are subject to control
- **Proteasomes** are giant protein complexes that bind protein molecules and **degrade** them



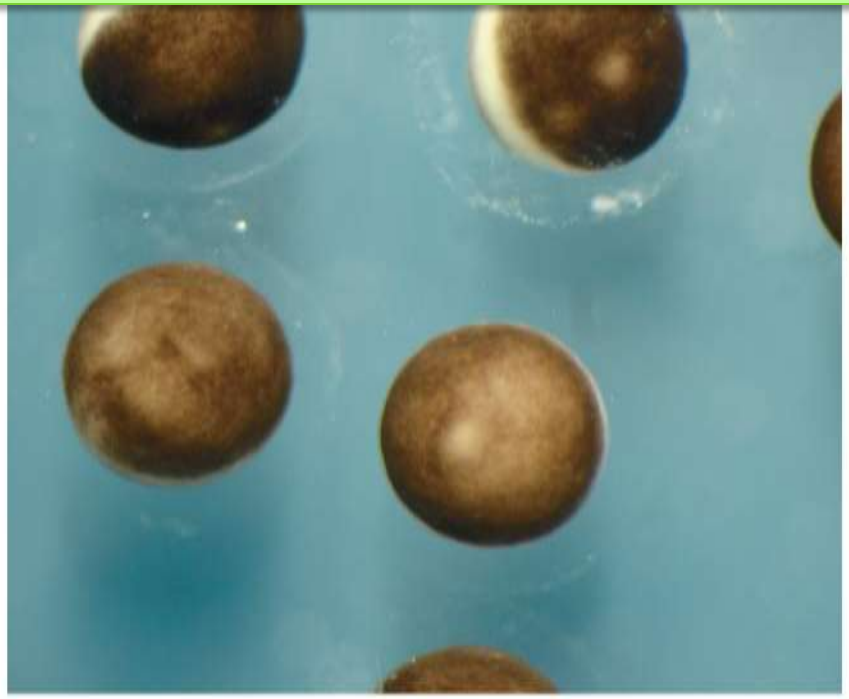
A program of differential gene expression leads to the different cell types in a multicellular organism

- During embryonic development, a fertilized egg gives rise to **many different cell types**
- Cell types are organized successively into **tissues, organs, organ systems,** and the whole **organism**
- Gene expression orchestrates the developmental programs of animals

A Genetic Program for Embryonic Development

- The transformation from zygote to adult results from cell division, cell differentiation, and morphogenesis

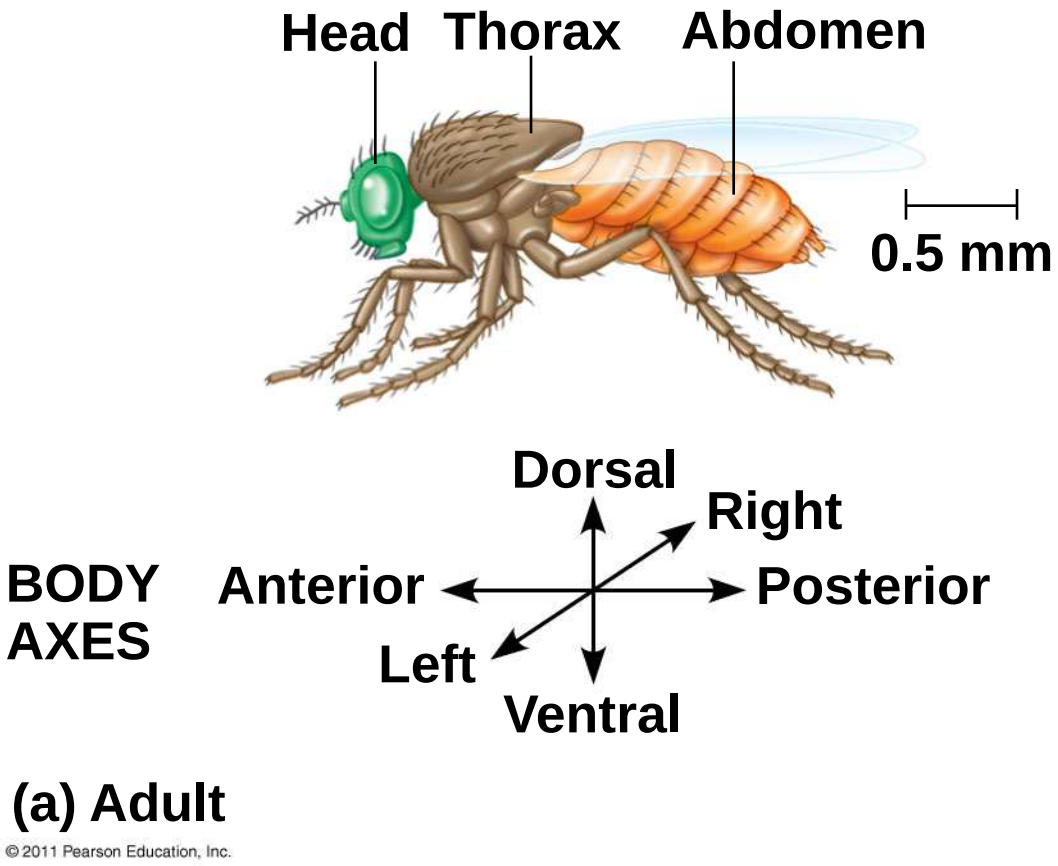
From fertilized egg to animal: What a difference four days makes



(a) Fertilized eggs of a frog

(b) Newly hatched tadpole

Key developmental events in the life cycle of *Drosophila*



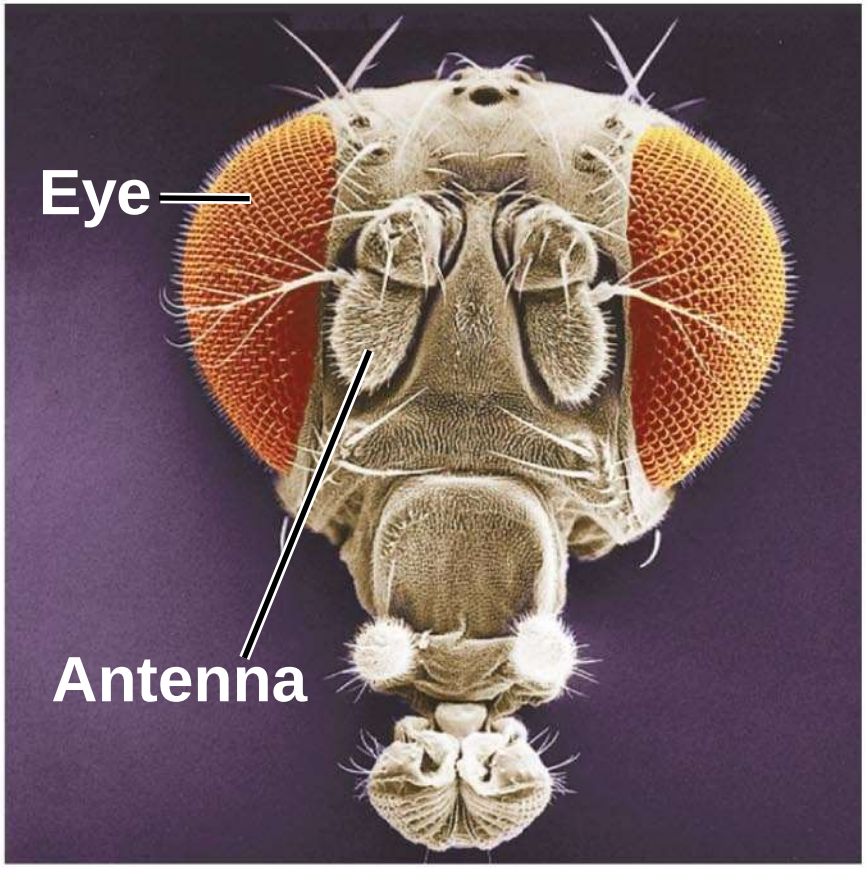
- **Cell differentiation** is the process by which **cells become specialized in structure and function**
- The physical processes that give an organism its shape constitute **morphogenesis**
- Differential gene expression results from genes **being regulated differently** in each cell type

Sequential Regulation of Gene Expression During Cellular Differentiation

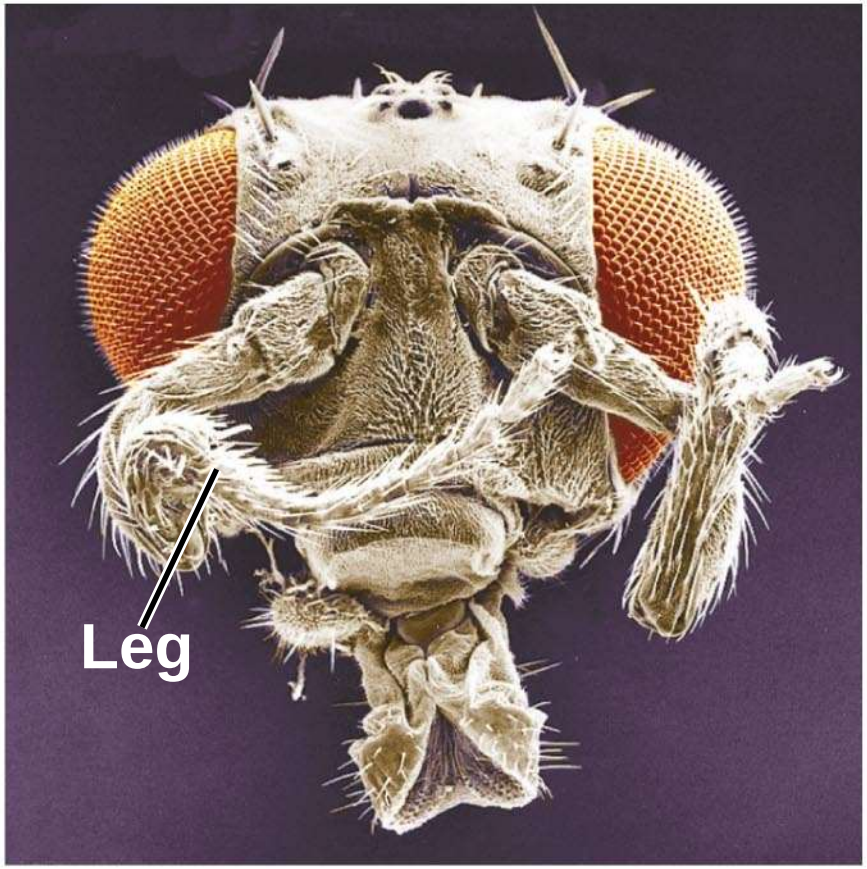
- In the process called **induction**, signal molecules **from embryonic cells** cause transcriptional changes **in nearby target cells**
- Thus, interactions between cells induce differentiation of specialized cell types

- **Determination** commits a cell to its final fate
- Determination **precedes** differentiation

Abnormal pattern formation in *Drosophila*



Wild type



Mutant

Questions ?

Questions ?