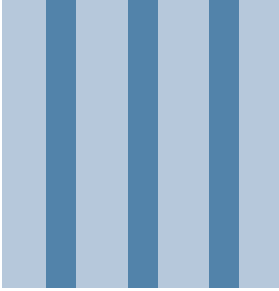


U N I T



Growth and Development



14

Gene Expression and Signal Transduction

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Each living cell contains a set of instructions for building the entire organism, consisting of genes linearly arranged in the form of chromosomes. This fundamental concept in biology began with Mendel's genetic studies with garden peas in 1865, and culminated with Watson and Crick's discovery of the structure of DNA in 1953. But the story did not end there. A new field of molecular biology arose focused on the structure, replication, and expression of genes. Genes encode proteins, and elucidation of the elaborate machinery involved in transcription and translation was one of the early triumphs of the new field of molecular biology. More recently, molecular biologists have sought to understand how gene expression is regulated, for it turns out that the genetic "instructions" found on the chromosomes are incomplete without a full complement of regulatory proteins from the cytoplasm to direct their activity. In this chapter we will review basic concepts in gene expression in prokaryotes and eukaryotes.

While molecular biologists were studying cell function from the gene outward, developmental biologists were tracking the signals that regulate development, both external and internal, from the "skin" inward. They discovered that developmental signals, such as light or hormones, involve specific receptors and typically require amplification in the form of "second messengers." Ultimately these second messengers regulate the activities of crucial processes, such as membrane transport or gene expression, which bring about the physiological or developmental response. Thus developmental and molecular biologists approach the same problem from opposite directions. The second part of this chapter provides an overview of various signaling mecha-

GENOME SIZE, ORGANIZATION, AND COMPLEXITY

Most Plant Haploid Genomes Contain 20,000 to 30,000 Genes

PROKARYOTIC GENE EXPRESSION

DNA-Binding Proteins Regulate Transcription in Prokaryotes

EUKARYOTIC GENE EXPRESSION

Eukaryotic Nuclear Transcripts Require Extensive Processing
Various Posttranscriptional Regulatory Mechanisms Have Been Identified

Transcription in Eukaryotes Is Modulated by *cis*-Acting Regulatory Sequences

Transcription Factors Contain Specific Structural Motifs
Homeodomain Proteins Are a Special Class of Helix-Turn-Helix Proteins

Eukaryotic Genes Can Be Coordinately Regulated
The Ubiquitin Pathway Regulates Protein Turnover

SIGNAL TRANSDUCTION IN PROKARYOTES

Bacteria Employ Two-Component Regulatory Systems to Sense Extracellular Signals

Osmolarity Is Detected by a Two-Component System
Related Two-Component Systems Have Been Identified in Eukaryotes

SIGNAL TRANSDUCTION IN EUKARYOTES

Two Classes of Signals Define Two Classes of Receptors
Most Steroid Receptors Act as Transcription Factors
Cell Surface Receptors Can Interact with G Proteins
Heterotrimeric G Proteins Cycle between Active and Inactive Forms

(Continued)

nisms found in living cells. The models presented are derived mainly from animal and microbial systems, in which they were first discovered. Related mechanisms in plants will be discussed in the various chapters of the text devoted to development, light, and hormones.

Activation of Adenylyl Cyclase Increases the Level of Cyclic AMP

**Activation of Phospholipase C Initiates the IP_3 Pathway
 IP_3 Opens Calcium Channels on the ER and on the Tonoplast
 Cyclic ADP-Ribose Mediates Intracellular Ca^{2+} Release Independently of IP_3 Signaling**

Some Protein Kinases Are Activated by Calcium–Calmodulin Complexes

Plants Contain Calcium-Dependent Protein Kinases

Diacylglycerol Activates Protein Kinase C

Phospholipase A_2 Generates Other Membrane-Derived Signaling Agents

In Vertebrate Vision, a Heterotrimeric G Protein Activates Cyclic GMP Phosphodiesterase

Nitric Oxide Gas Stimulates the Synthesis of cGMP

Cell Surface Receptors May Have Catalytic Activity

Ligand Binding to Receptor Tyrosine Kinases Induces Autophosphorylation

Intracellular Signaling Proteins That Bind to RTKs Are Activated by Phosphorylation

Ras Recruits Raf to the Plasma Membrane

The Activated MAP Kinase Enters the Nucleus

Plant Receptorlike Kinases Are Structurally Similar to Animal Receptor Tyrosine Kinases

SUMMARY