BACKGROUND INFORMATION

Gene Expression

Gene expression is the process in which the information stored in DNA is used to produce a functional gene product. Gene products are either proteins or noncoding RNAs, such as tRNA and rRNA, which play essential roles in protein synthesis, but do not code for proteins. Gene expression is regulated throughout the lifespan of an individual cell to control the cell's functions, such as its metabolic activity. Gene expression plays a critical role in the morphological changes that take place in a developing embryo and fetus and in the differentiation of stem cells to form specialized cells.

The expression of protein-coding genes is regulated at a number of steps, including 1) transcription of DNA to form RNA, 2) processing of the RNA product, 3) translation of mRNA to produce a protein, and 4) post-translational modification of the protein product. Our classroom activity introduces you to controls that interact directly with DNA to regulate the transcription of genes into mRNA by RNA polymerase, the enzyme that links ribonucleotides together to form RNA. Transcription is regulated by changes in the DNA and associated histone proteins that affect the condensation of the DNA (when long strands of DNA are tightly coiled into chromosomes) and by proteins called **transcription factors**. These transcription factors serve as activators or repressors of transcription. **Activators** increase the binding of RNA polymerase to the promoter of a gene, thus increasing the rate of transcription. **Repressors** bind at or near the promoter and interfere with the activity of RNA polymerase.

In prokaryotes, usually clusters of genes are under the control of one promoter that is adjacent to the gene sequences. The promoter is a stretch of DNA where RNA polymerase first binds before the initiation of transcription. These clusters of genes adjacent to a single promoter are called operons. The best-known example of this is the lactose operon of E. coli, made up of three genes involved in lactose metabolism. The operon includes the promoter, the three protein-coding genes, and a regulatory sequence called an operator. This arrangement allows the three genes to be turned on or turned off at the same time.

In eukaryotes, the regulation of gene expression is more complex. Genes are generally regulated individually rather than in operons. Each gene has its own promoter and several regulatory sequences called enhancers, some of which may be distant from the gene and its promoter. Multiple activators, co-activators, and repressors might be involved in the regulation of a eukaryotic gene by affecting the condensation of the DNA, by interacting with the promoter, or by inter- acting with regulatory sequences. This complex regulation allows the rate of transcription to be modulated as needed.