Flow of Genetic Information - Transcription & RNA Processing

1. Overview of flow of genetic information including biomolecules involved and name of the cellular processes
2. Comparison of flow of information in prokaryotic and eukaryotic cells
3. Comparison of structures and functions of DNA and RNA
4. Overview of molecular nature of genes, the two strands of DNA, mRNA, and proteins.
5. Mechanism of RNA transcription: steps and molecular machinery
6. Split genes of eukaryotic cells
7. From pre-mRNA to mature mRNA: mechanism of pre-RNA processing and modification in eukaryotic cells
8. Role of introns
Flow of Genetic Information

from DNA → RNA → protein

is also known as

The central “dogma” of molecular biology

**Dogma:** A set of beliefs that people accept without any doubts
(a) Bacterial cell
(b) Eukaryotic cell
Flow of Genetic Information

Prokaryotic

DNA $\rightarrow$ mRNA $\rightarrow$ protein

Polymers of
(name the monomer of each)

Eukaryotic

DNA $\rightarrow$ pre-mRNA $\rightarrow$ mRNA $\rightarrow$ protein

Polymers of
(name the monomer of each)

Name the process and its cellular Compartment (?)
Transcription, RNA processing, and translation are the processes that link DNA sequences to the synthesis of a specific polypeptide chain.
DNA and RNA are polymers of nucleotides

**Chemical Structure of DNA**

- **Sugar-phosphate backbone**
- **Phosphate group**
- **Nitrogenous base**
- **Sugar**

**DNA Polynucleotide**

**DNA Nucleotide**

- **Nitrogenous base** (A, G, C, or T)
- **Sugar** (deoxyribose)
- **Phosphate group**

**Thymine (T)**

**Review of Nucleic Acid Chemical Structure**
DNA has four kinds of nitrogenous bases
• A, T, C, and G

Thymine (T)  Cytosine (C)  Adenine (A)  Guanine (G)

Pyrimidines  Purines

RNA has a slightly different sugar & U instead of T
<table>
<thead>
<tr>
<th></th>
<th>DNA</th>
<th>RNA</th>
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<tbody>
<tr>
<td># of strands</td>
<td></td>
<td></td>
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<tr>
<td>Pentose sugar</td>
<td></td>
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<tr>
<td>Nitrogen bases</td>
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<tr>
<td>Function</td>
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Class Q
• Genome: Totality of DNA in a cell

• Chromosome: a very long stretch of DNA with a large number of genes each with individual information to direct the cell to make a particular protein

• Gene: a linear DNA sequence of nucleotides that specifies the sequence of a functional product (the sequence of amino acids of a polypeptide)
From the language of DNA to the language of proteins

DNA molecule

Gene 1

Gene 2

Gene 3

DNA strand (template)

mRNA

TRANSCRIPTION

mRNA

Codon

TRANSLATION

Protein

Amino acid

Trp

Phe

Gly

Ser
Template and coding strands of DNA

- The two strands of DNA have complementary sequences - (template/anti-sense and sense coding strand)

- RNA transcripts are single stranded and are made $5' \rightarrow 3'$

- Only one DNA strand, the template is used

*If given the sequence of one of the strands, predict the sequences of the other two using the base-pairing rule*
1. Write down the sequence of the RNA transcript using the above template.

2. Write down the sequence of the coding strand 5’ to 3’ direction.

3. Write down the RNA transcript if the coding strand was the template strand.

Class Q’s
The Transcription Process

Where does transcription of a particular gene begin and where does it end?

- Promoter & terminator DNA sequences

What biomolecules are involved?

- DNA
- RNA polymerase
- Ribonucleotides

What are the steps involved?

- Three stages of transcription: initiation, elongation, and termination.
Which of the two strands of DNA serve as the template for transcription is dictated by the position of the promoter.
Transcription in Prokaryotes

**INITIATION**

RNA polymerase binds to the promoter and melts a short stretch of DNA.

**ELONGATION**

Sigma factor then dissociates from RNA polymerase, leaving the core enzyme to complete transcription. The RNA transcript is synthesized in the 5' to 3' direction as the enzyme adds nucleotides to the 3' OH of the growing chain.

**TERMINATION**

When RNA polymerase encounters a terminator, it falls off the template and releases the newly synthesized RNA.
• Transcription starts when RNA polymerase binds to the promoter sequence

• Genes are read 3’->5’, creating a 5’->3’ RNA molecule.

• Only RNA polymerase is needed in prokaryotic cells.
Transcription Initiation in Eukaryotes

- Protein-transcription factors bind before RNA polymerase.
- A transcription initiation complex forms before RNA transcription starts.
Transcription
Elongation

- RNA polymerase add complementary nucleotides 5’->3’
- The template strand of a gene is read 3’->5’
Transcription stops at DNA sequences known as terminator sequences

**Prokaryotes**: hairpin loop structure

**Eukaryotes**: terminator sequence, AAUAAA.
Split genes of eukaryotes

- Expressed sequences (exons) separated by non-coding intervening sequences (introns)

- Both exons and introns are present in the primary transcript (pre-mRNA)

- Introns are cut out (excised) and exons are pasted together (spliced) during RNA processing
Summary of post-transcriptional modification to pre-mRNA

- 5’ cap: protection against nucleases binding to ribosomes
- 3’ poly A tail: transport to cytoplasm efficient translation
- RNA splicing to connect the exons after removal of introns

Spliceosomes
http://highered.mcgraw-hill.com/sites/0072437316/student_view0/chapter15/animations.html#
Processing of pre-mRNA in eukaryotes

Polyadenylation of mRNA
http://vcell.ndsu.edu/animations/mrnaprocessing/movie-flash.htm

Spliceosomes
http://highered.mcgraw-hill.com/sites/0072437316/student_view0/chapter15/animations.html#

Real speed animation
http://www.dnai.org/a/index.html

Importance of 5’ and 3’ ends for translation

Detailed RNA processing

Overview of Flow of information in eukaryotic cells
http://bcs.whfreeman.com/pierce1e/pages/bcs-main.asp?v=chapter&s=13000&n=00020&i=13020.02&o=|00010|00020|00030|00060|&ns=0
Comparison of pre-mRNA and mRNA

![Comparison of pre-mRNA and mRNA diagram](image)
- Capped at 5’ end modified guanine
- Tailed with a poly A (20-250) adenines
- Not all the sequences of the mRNA are coding
  Leader (5’-UTR) and Trailer (3’-UTR) sequences are non-coding
RNA splicing functions and advantages

– Control of gene expression
  • Sequences
  • Speed of mature mRNA production

– **Alternative RNA splicing** - one gene can encode for more than one polypeptide, within an organism.

• Proteins discrete structural and functional regions called **domains**.

• Different exons code for different domains of a protein.
Comparison of flow of Genetic Information

Prokaryotic  Eukaryotic

A. Transcription

B. RNA processing

C. Translation

Class Q: Specify the name of the biomolecules involved and the cellular compartment where each process takes place.
The snRNA acts as a **ribozyme**, an RNA molecule that functions as an enzyme.

In a few cases, intron RNA can catalyze its own excision without proteins or extra RNA molecules.

Are all biological catalysts made of protein?

Ribozyme animation

http://www.youtube.com/watch?v=eGKg5i4FHHw