DNA to RNA to Protein

Understanding the Central Dogma of Biology
Structure of Cells

- microtubules
- mitochondrion
- centriole
- vesicle
- cytosol
- nuclear envelope
- nuclear pore
- nucleolus
- Golgi complex
- lysosome
- flagellum
- plasma membrane
- rough endoplasmic reticulum
- ribosomes
- smooth endoplasmic reticulum
The Cell as a Factory

- Energy production
- Project management
- Routing
- Facilities
- Data retrieval
- Data storage
- Data management
- Data processing
- Shipping
- Waste management
- Transportation
- Communications
- Manufacturing
- Machine shop
- Packaging
What are Cells Made of?

- Membranes (fats)
- Proteins
- Carbohydrates (sugars)
- Cofactors (vitamins)
- Nucleic acids
How is a Cell Assembled?

• There must be “information” that specifies the assembly of cell parts
• DNA contains the information necessary to build a cell
• The mechanisms by which DNA gives rise to cells and organisms is at the heart of the “central dogma” of biology
Central Dogma of Biology

DNA $\rightarrow$ RNA $\rightarrow$ PROTEIN

Data storage $\rightarrow$ Readout $\rightarrow$ Execution
What is DNA?

- DNA is deoxyribonucleic acid
- It is a polymer of nucleotides
- It encodes the information necessary to build a cell
- It allows the storage and replication and execution of cellular information
Structure of Nucleotides

Bases

- A (Adenine)
- G (Guanine)
- C (Cytosine)
- U (Uracil)
- T (Thymine)

Sugars

- Ribose
- 2'-deoxyribose
- Adenosine
- 2'-deoxythymidine
Nucleotides Polymerize to Form Nucleic Acids
Base-pairing Controls Formation of Second Polymer Chain
Base-complementation Allows DNA Replication

Base-pairing precedes polymerization

DNA polymerase makes DNA
The Two Strands of DNA are Complementary
Central Dogma of Biology

DNA → RNA → PROTEIN

Data storage → Readout → Execution
What are Proteins?

- Proteins are polymers of amino acids
- Each protein has a unique sequence of amino acids
- The sequence of amino acids specifies protein shape and function
Proteins Have Many Functions in Cells

- They make most of the structures in cells
- They are the enzymes that break down food
- They are responsible for building new parts
- They act as the eyes and ears of cells

*Most cell functions are carried out by proteins*
Proteins Make Cellular Structures

From primary transcript

LLCDGGALPTYSLQIAALMRRTLGGDEHICVLISTH

To folded protein

To assembled structure

Cells are built from proteins (and some other stuff)
What are Amino Acids?

Although the amide N is not charged at neutral pH, it is polar.
Amino Acids Polymerize to Form Proteins

\[
\text{H}0\text{H}0
\text{R}R\text{R}R\text{R}
\text{N-C-C-N-C-C-N-}
\text{H}R\text{H}R\text{H}
\]
Sequence of Protein Dictates its Folding Pattern

- Unfolded polypeptide
- Folded conformation in aqueous environment
How Does DNA Specify the Sequence of a Protein?

• A DNA sequence must be “decoded” to make a protein
• This decoding requires creation of an RNA template
• Creation of “messenger RNA” is called transcription
• Creation of protein from the mRNA is called translation
Central Dogma of Biology

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- Data storage
- Readout
- Execution
Two Types of RNA

DNA
ATGGCCTAAGCTCTGA

mRNA
UACCGGAUUCGAGACU

mRNA looks like DNA and is essentially a copy of a gene

“transfer” RNA (tRNA) is an adaptor used in protein synthesis
Information Flow in Protein Synthesis
Where Do Genes Start and Stop?

START SIGNAL

5'—TAGTGTATTTGACATGATAGAGCAGCTCCTACTCATAG—3'

STOP SIGNAL

5'—CCCACAUGCGCCAGUCCGCGCCAGUCCGCUUUU—OH

start site
Synthesis of RNA
Understanding the Genetic “Code”

Any strand of RNA

......CUCAGCGUUUACCAU...

Can be read in three different “frames”
Genetic Code is Translated by Two Sequential “Adaptors”

Net result: tryptophan is selected by its codon
Proteins are Made on Ribosomes
Information Flow is Simpler in Procaryotics
The Structure of Genes in Eucaryotes Can Be Complex
Relationship Between Genes and Proteins
So What is Next?

- How does the amino acid sequence of a protein specify its function?
- How about those other parts of cells (such as membranes)? How are they made?
- How are cellular processes regulated?
- How do we study cells and biochemical processes?