Lecture 16
DNA, RNA, and Heredity

Astronomy 141 – Winter 2012

This lecture is about DNA and RNA, and their role in cell function, heredity, and evolution.

All life on Earth uses DNA to store and transmit an organism's cellular "operating instructions".

DNA is a double-helix polymer formed of a sugar and phosphate backbone and 4 base-pair molecules.

Genetic code (genes and genome) and the mechanism of replication.

RNA determines a cell's function, synthesizing proteins and enzymes.

Mutations, changes in DNA instructions, are the molecular basis of evolution.

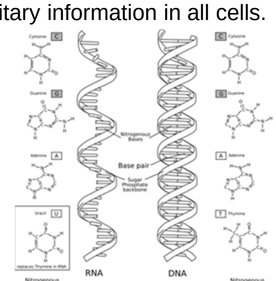
Nucleic Acids are the basis for the storage and transmission of hereditary information in all cells.

DNA
Deoxyribonucleic Acid

Encodes instructions for making proteins and RNA.

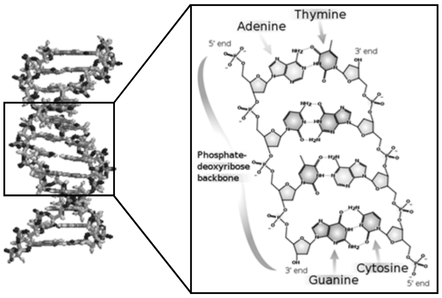
RNA
Ribonucleic Acid

Determines a cell's function and manufactures proteins & enzymes.



DNA stores the "operating instructions" for a cell.
RNA carries out the instructions and determines cell function.

DNA is a long double helix structure consisting of a pair of sugar-phosphate backbones connected by four nucleobases that come in pairs.



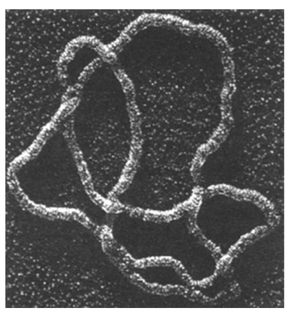
DNA is a very long-chain polymer molecule consisting of a very large number of base pairs.

Human DNA contains nearly 3 Billion base pairs

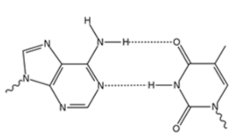
Sequences of base pairs code various cell functions:

- protein synthesis
- RNA synthesis
- regulation of synthesis

Unit is a "*gene*" which codes for a single function.

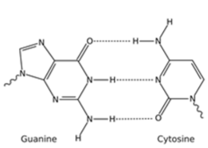


The "language" of DNA is written in the sequence of base pairs that runs along the helix.



Adenine & Thymine

Forms the A-T pair



Guanine & Cytosine

Forms the G-C pair

The sequence of base pairs codes for protein building by mapping to specific amino acids.

Proteins are chains of amino acids.

Three base-pair “words” code for specific amino acids, or instructions like “start” and “stop” (ends of the protein chain).

The string of words specifies the sequence of amino acids that make a particular protein.

Three-base “language” allows for $4^3 = 64$ combinations.

Common genetic language of all life on Earth.

second base

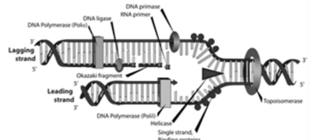
first base	T	C	A	G	third base
T	TTT, TTC: Phenylalanine	TCT, TCC, TCA, TCG: Serine	TAT, TAC: Tyrosine	TGT, TGC: Cysteine	T, C
T	TTA, TTG: Leucine		TAA stop; TAG stop	TGA stop; TGG Tryptophan	A, G
C	CTT, CTC, CTA, CTG: Leucine	CCT, CCC, CCA, CCG: Proline	CAT, CAC: Histidine	CGT, CGC, CGA, CGG: Arginine	T, C
C			CAA, CAG: Glutamine		A, G
A	ATT, ATC, ATA: Isoleucine	ACT, ACC, ACA, ACG: Threonine	AAT, AAC: Asparagine	AGT, AGC: Serine	T, C
A	ATG Met or start		AAA, AAG: Lysine	AGA, AGG: Arginine	A, G
G	GTT, GTC, GTA, GTG: Valine	GCT, GCC, GCA, GCG: Alanine	GAT, GAC: Aspartic acid	GGT, GGC, GGA, GGG: Glycine	T, C
G			GAA, GAG: Glutamic acid		A, G

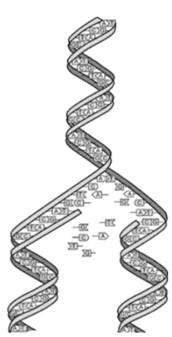
The double helix structure of DNA allows for its replication.

Helix unzips, splitting at the base pairs.

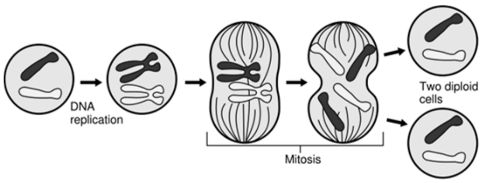
Each single strand’s complementary base pairs are added by an enzyme called DNA polymerase.

Result is a perfect copy of the DNA.





The replication of DNA inside a cell is the first step of cell division.



DNA resides in the chromosomes.

Each chromosome is copied exactly.

Each daughter cell inherits an exact copy of the DNA instructions

RNA is a single-stranded polymer with a different backbone that uses Uracil instead of Thymine.

Ribose sugar and phosphate backbone.

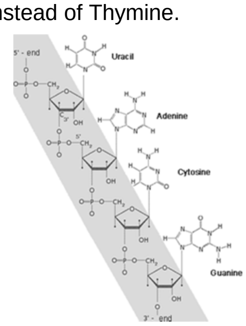
Adenine pairs with Uracil
Guanine pairs with Cytosine

RNA plays three roles in cells:

Copies instructions for protein synthesis from DNA (mRNA)

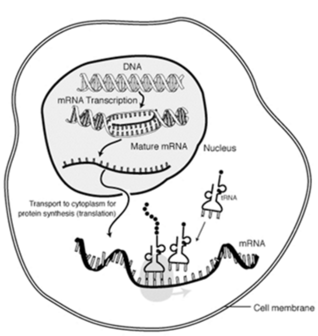
Transports amino acids to the synthesis site (tRNA)

Catalyzes protein synthesis (rRNA)



Transcription:
mRNA copies instructions from DNA in the nucleus and carries them to the synthesis site (ribosome).

Translation:
tRNA gathers amino acids and transports them to the ribosome where rRNA catalyzes protein synthesis on the mRNA



Copying errors during DNA replication or RNA transcription permanently change base sequences.

Original:	The big dog bit the red fox
Base Replacement:	The big dog qit the red fox
Base Insertion:	The big dro gbi tth ere dfo x
Base Deletion:	The big dgb itt her edf ox o
Word Insertion:	The big dog bit xyz the red fox
	The big dog bxy zit the red fox

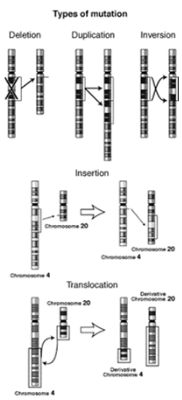
"Mutations" are changes in the DNA's instructions.

Some mutations have no effect (e.g., occur on non-coding sequences)

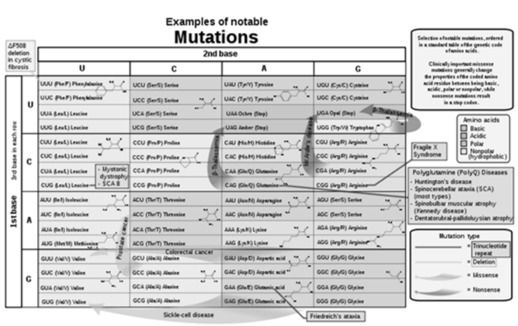
Some make subtle changes in the organism (e.g., eye or hair color)

Some can make bigger changes

Some mutations are harmful
- cause diseases (like cancer)
- kill the cell outright



Examples of notable, disease-causing mutations.



Mutations are the source of the genetic variations that are crucial for evolution.

Once a mutation occurs, if the cell survives, it is passed along to later generations (heredity)

If the mutation confers an adaptive advantage, gets amplified by natural selection over many generations.

Can also be amplified by genetic drift (changes in the frequency of variation).

Mutation is the molecular basis of evolution.

A requirement of life is having a means of storing and transmitting functional instructions (heredity).

Implications for Life elsewhere:

- Does life on other worlds have analogs of DNA and RNA?
- Are there other molecules that perform this function?
- Longer words or more bases?