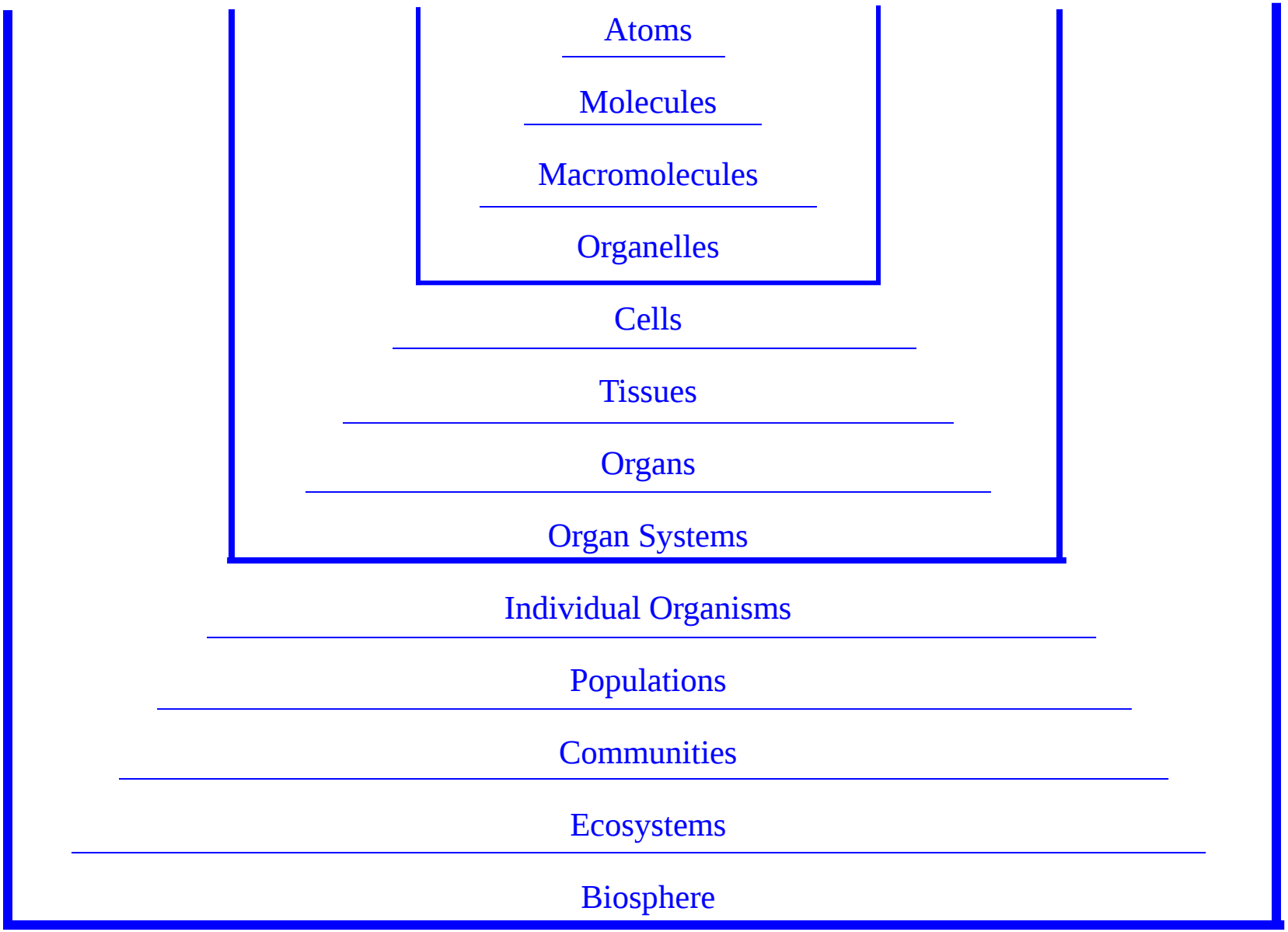
WHAT IS BIOLOGY?

- Technically, the "study" (Gr =*logos)* of "life" (Gr = *bio*s)
- Where do we draw the line between living and non-living entities?
- For examples: Are viruses alive?
  - * They consist of only a protein coat and an inner core of nucleic acid
  - * They can reproduce only inside living cells
  - * They can be crystallized and kept in a bottle for years and still infect their host cells

What Makes Something Alive?

1. Living organisms take in energy and/or nutrients from the environment.
2. Living organisms sense and respond to the environment in controlled ways.
3. Living organisms grow and reproduce.
4. Living organisms contain genetic material.
5. Living organisms demonstrate homeostasis: the ability to regulate the internal environment to keep it within certain limits.
6. Living organisms have the capacity to evolve.

Hierarchy in Biology

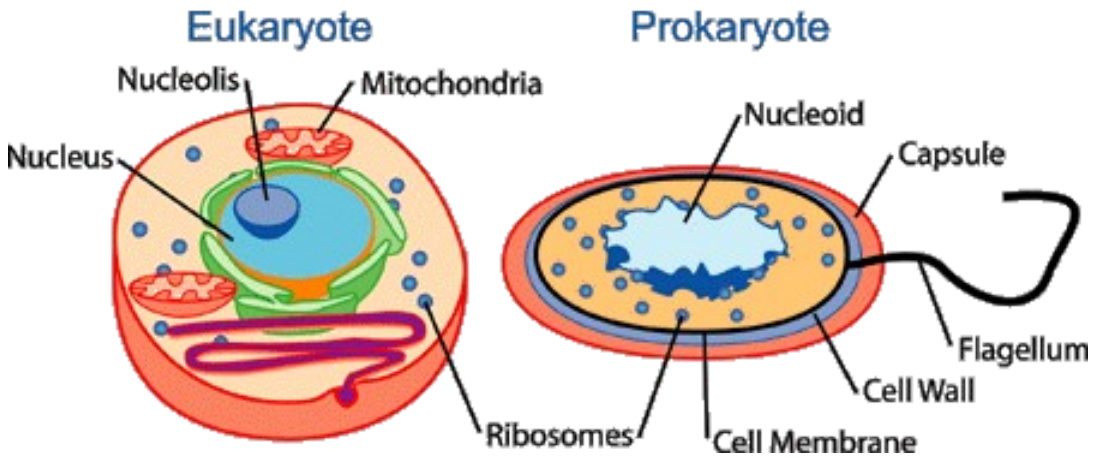


Meet the cell

Hi! I'm Sammy Cell.

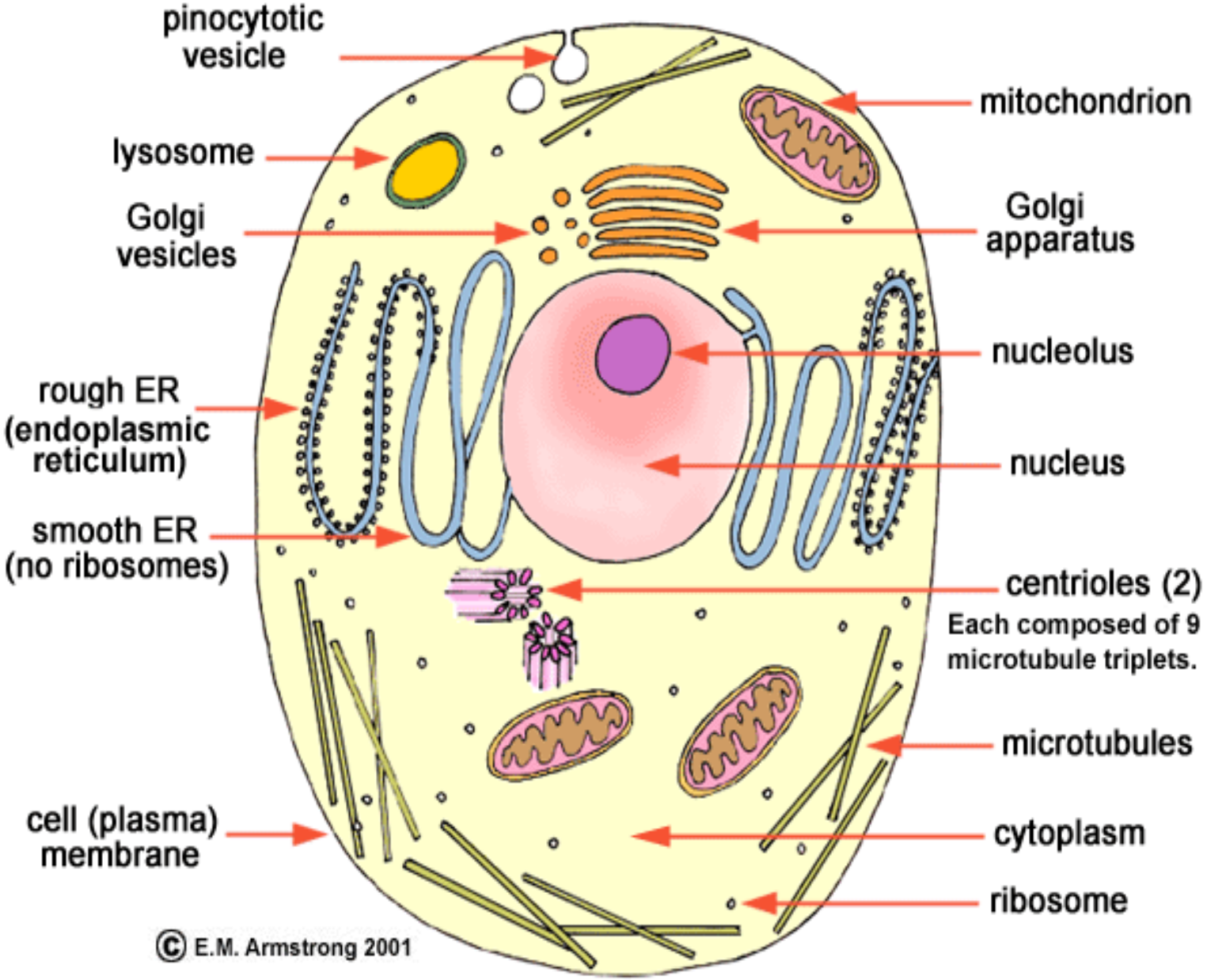
I am an animal cell. I am microscopic and live inside the human body along with billions of other cells identical to me.

Two types of organisms*



* Every biological ‘rule’ has exceptions!

Animal cell


pinocytotic vesicle
mitochondrion
lysosome
Golgi vesicles
Golgi apparatus
nucleolus
rough ER (endoplasmic reticulum)
nucleus
smooth ER (no ribosomes)
centrioles (2)
Each composed of 9 microtubule triplets.
microtubules
cell (plasma) membrane
cytoplasm
ribosome
© E.M. Armstrong 2001

Nucleus: administrative center of the cell

- It consists of chromatin, the unstructured form of the cell's DNA that will organize to form chromosomes during mitosis or cell division.
- It coordinates the cell's activities, which include intermediary metabolism, growth, protein synthesis, and reproduction (cell division).
- Occupies about 10 percent of a cell's volume, making it the cell's most prominent feature.

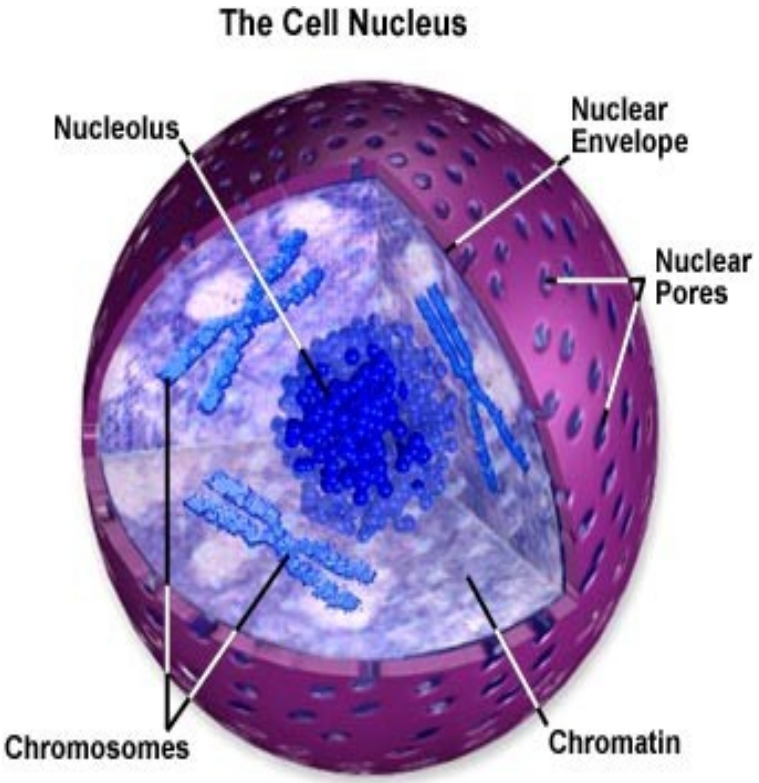
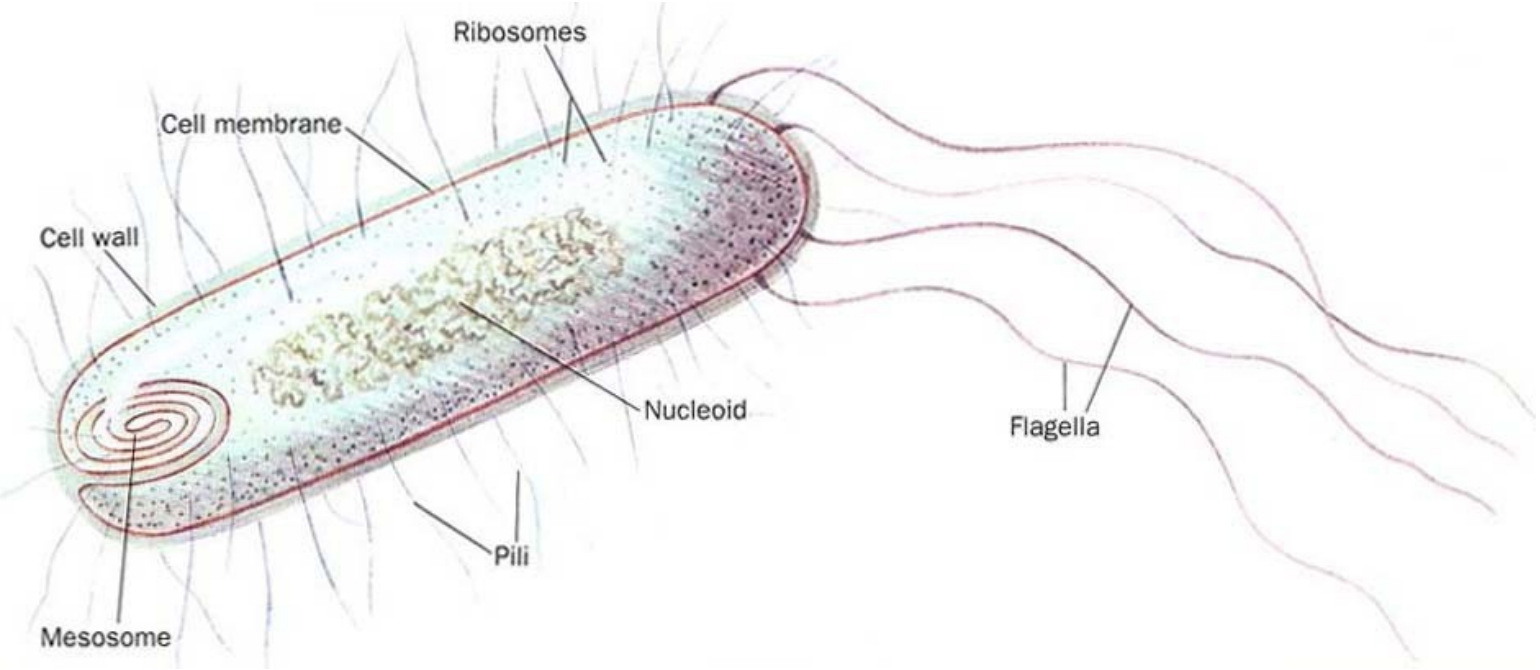


Figure 1



A schematic diagram of a prokaryotic cell

Prokaryotic vs. Eukaryotic

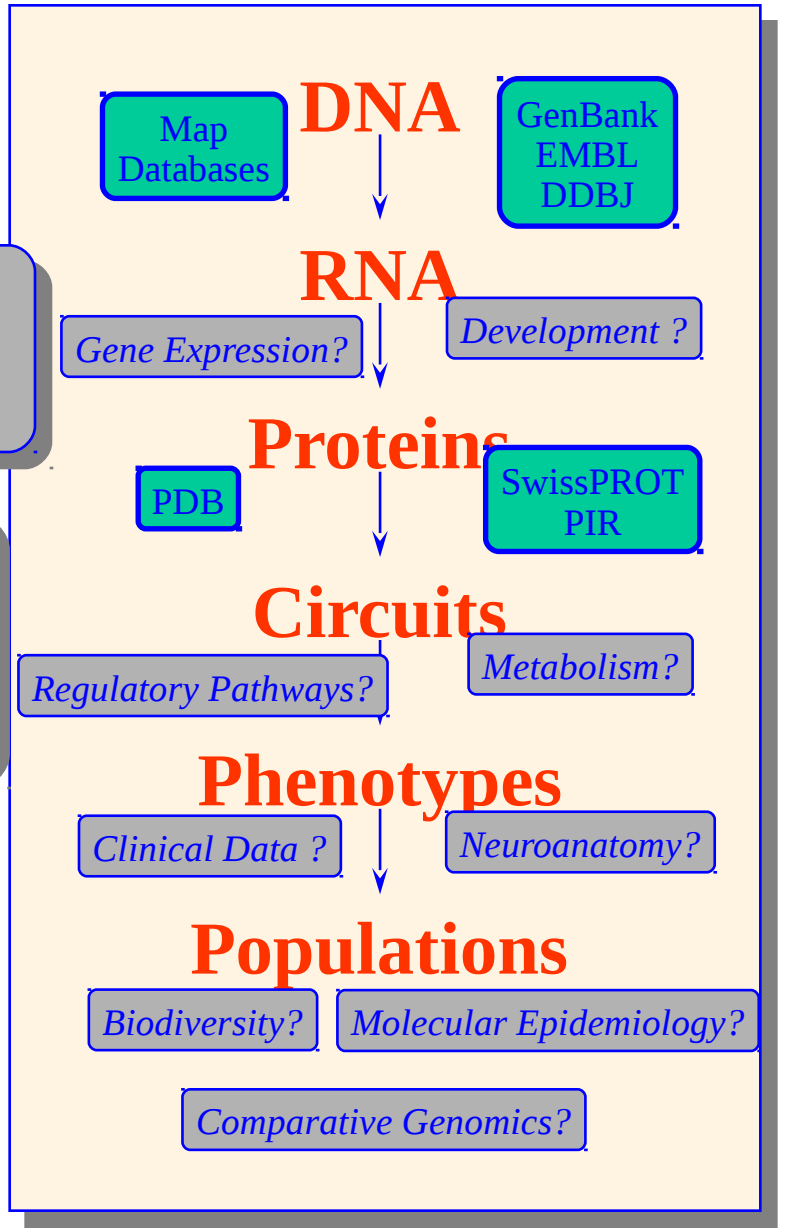
Type of cell	Definition	Examples
Eukaryotic	Cell that contains organelles, larger than Prokaryotic cells	Majority of living cells
Prokaryotic	Cells that lack organelles, smaller than Eukaruotic cells	Mostly single-celled organisms

Fundamental Dogma

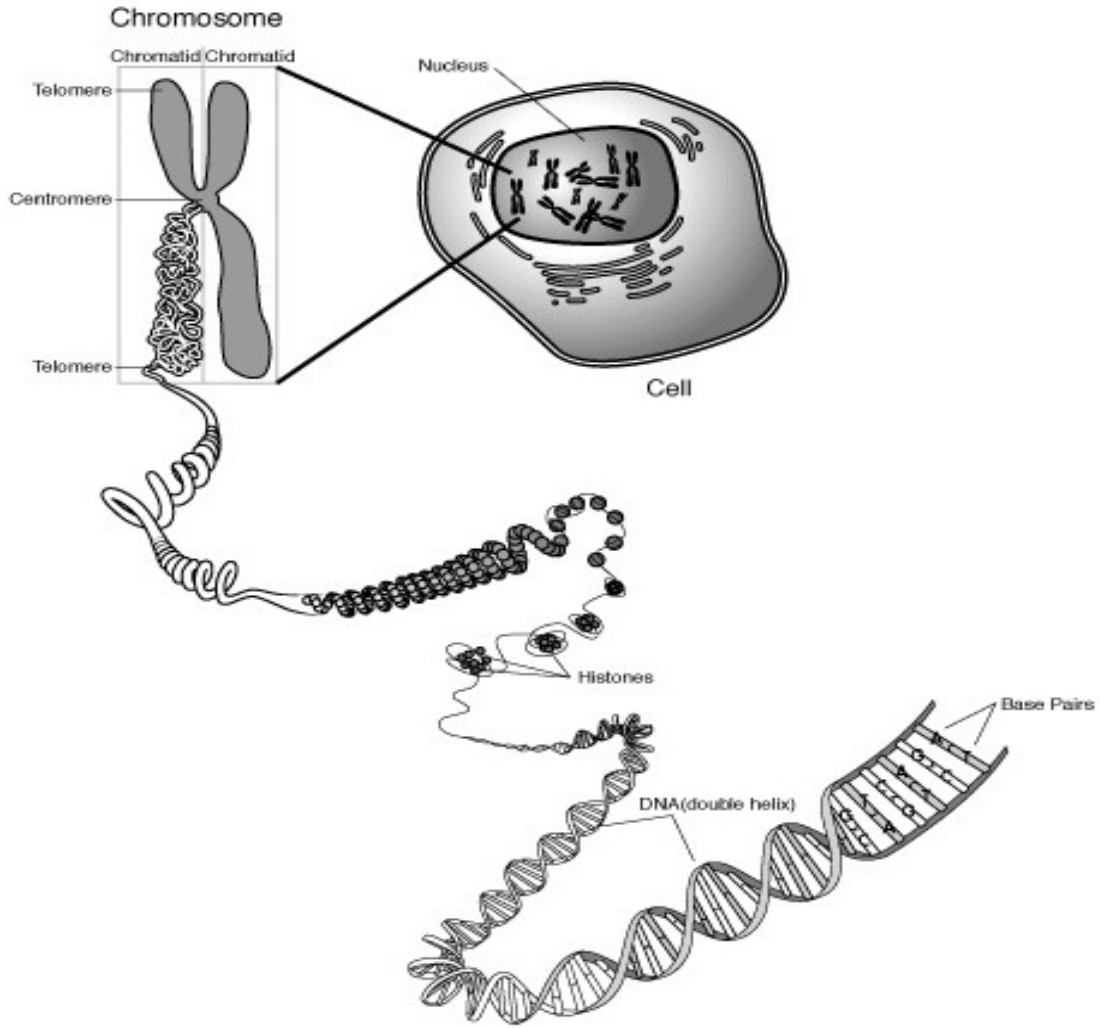
Although a few databases already exist to distribute molecular information,

the post-genomic era will need many more to collect, manage, and publish the coming flood of new findings.

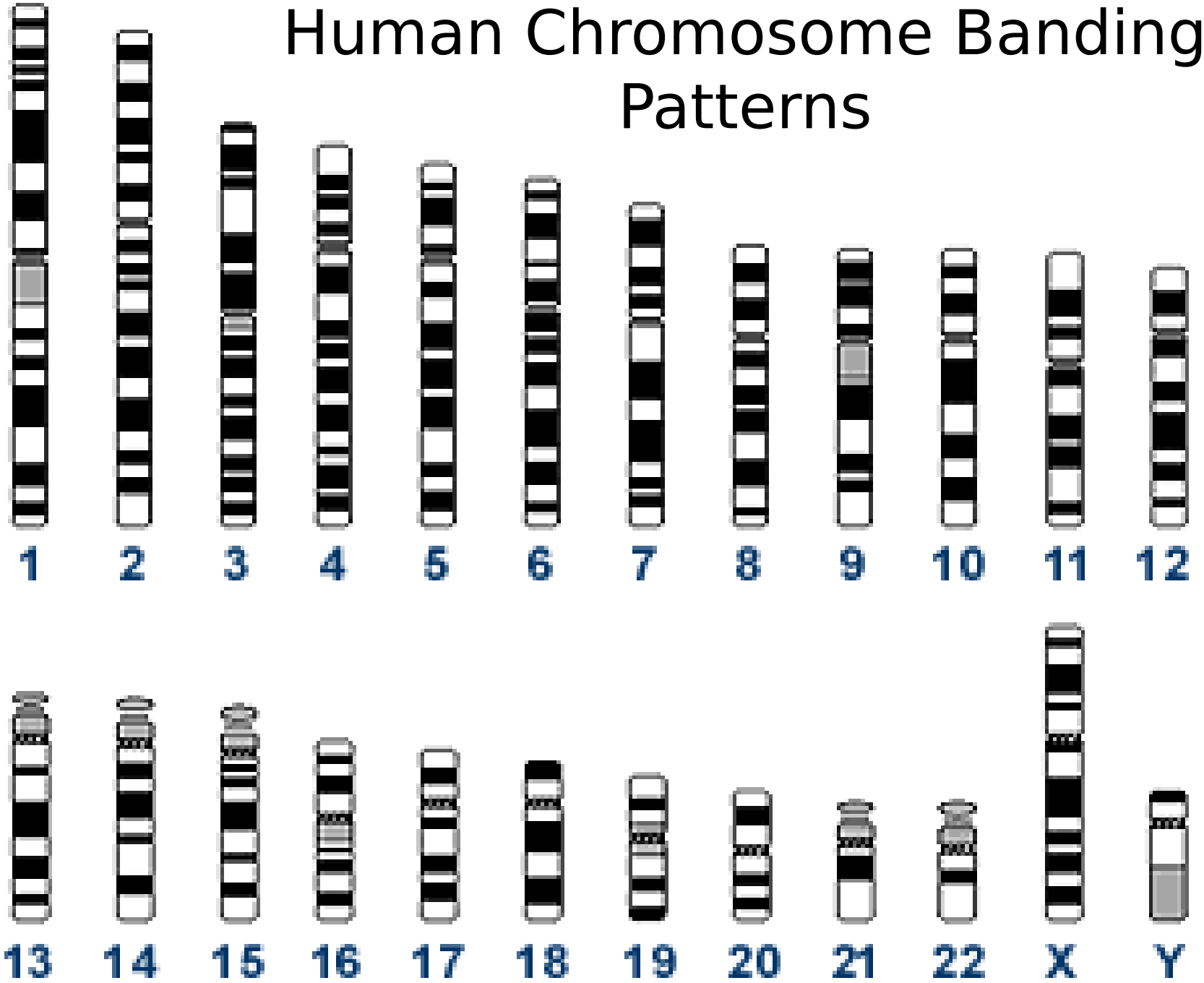
If this extension covers functional genomics, then "functional genomics" is equivalent to biology.



Chromosomes and DNA



Human Chromosome Banding Patterns



Human Chromosomes

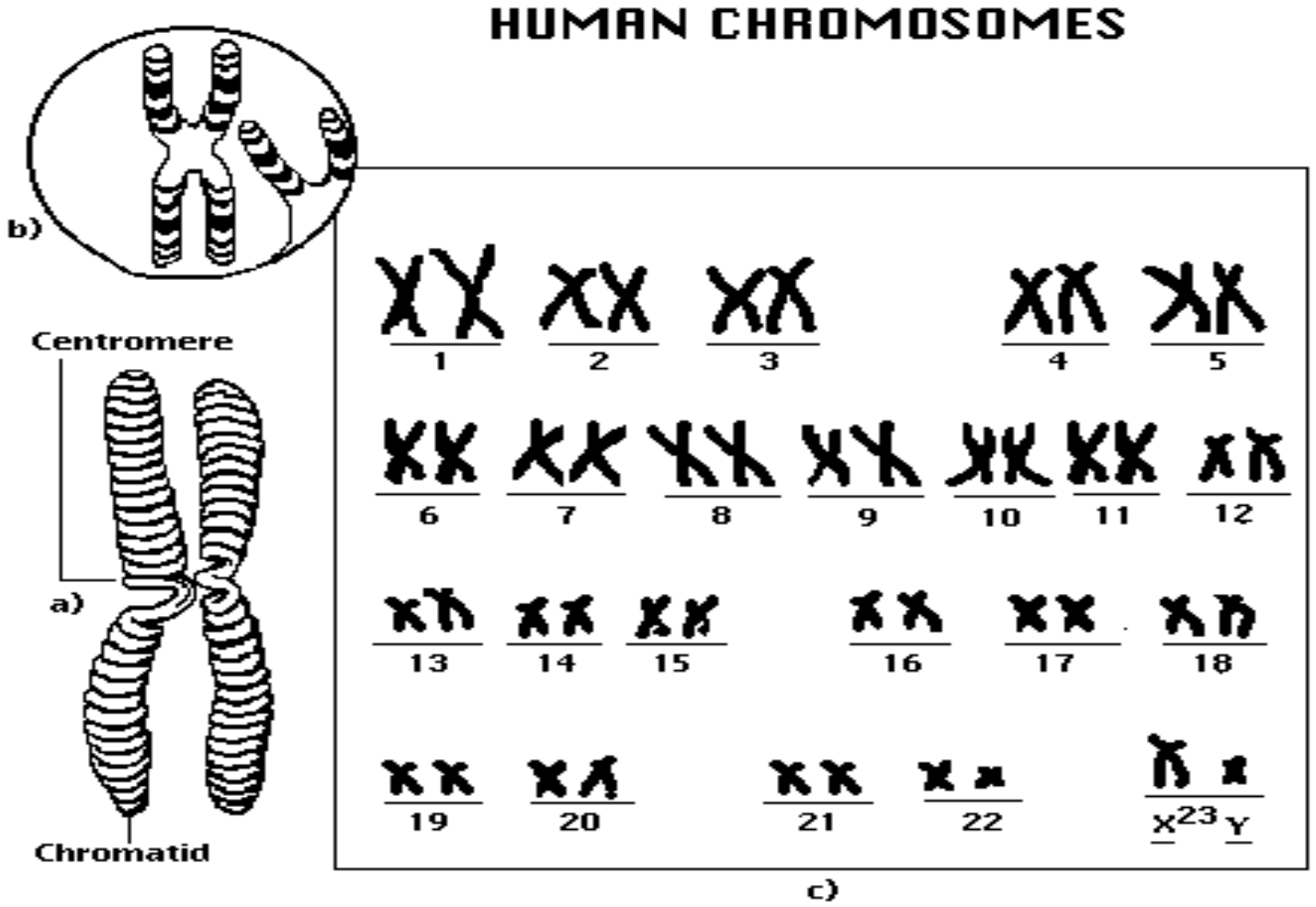


Table 2.3 Chromosome Number in Selected Organisms

Organism	Diploid Number ($2n$)	Haploid Number (n)
Human (*Homo sapiens*)	46	23
Chimpanzee (*Pan troglodytes*)	48	24
Gorilla (*Gorilla gorilla*)	48	24
Dog (*Canis familiaris*)	78	39
Chicken (*Gallus domesticus*)	78	39
Frog (*Rana pipiens*)	26	13
Housefly (*Musca domestica*)	12	6
Onion (*Allium cepa*)	16	8
Corn (*Zea mays*)	20	10
Tobacco (*Nicotiana tobacum*)	48	24
House mouse (*Mus musculus*)	40	20
Fruit fly (*Drosophila melanogaster*)	8	4
Nematode (*Caenorhabditis elegans*)	12	6

Human somatic cells have 46 chromosomes
diploid number (2n) = 46

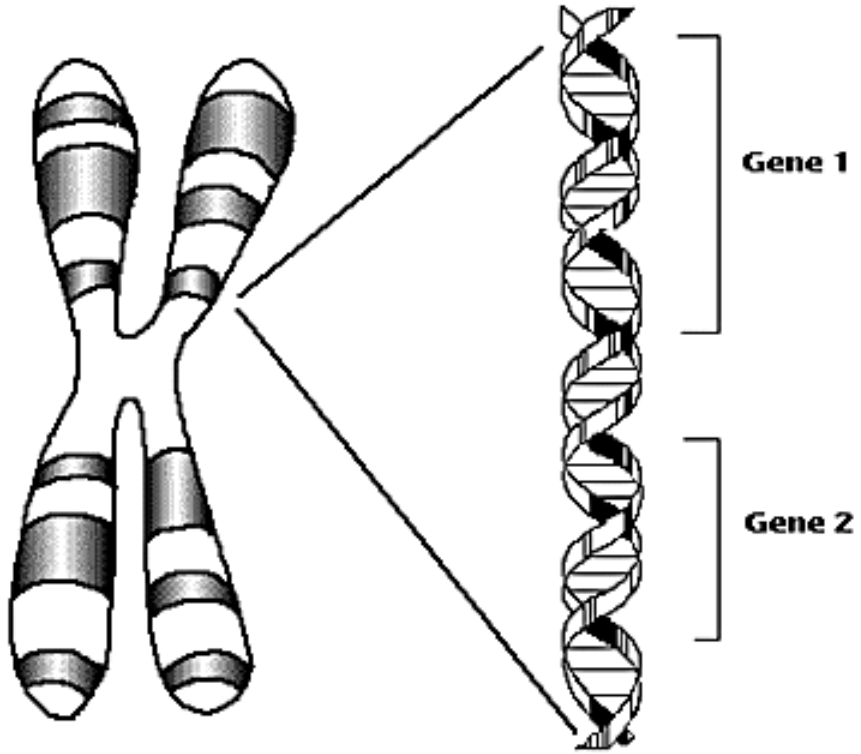
23 from mom - 23 from dad

22 pairs are autosomes –true homologous pairs

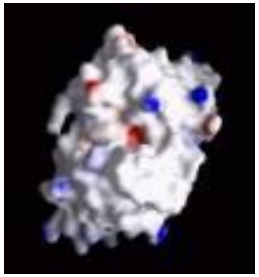
1 pair is not necessarily homologous

- sex chromosomes
females are XX
males are XY – a non homologous pair.

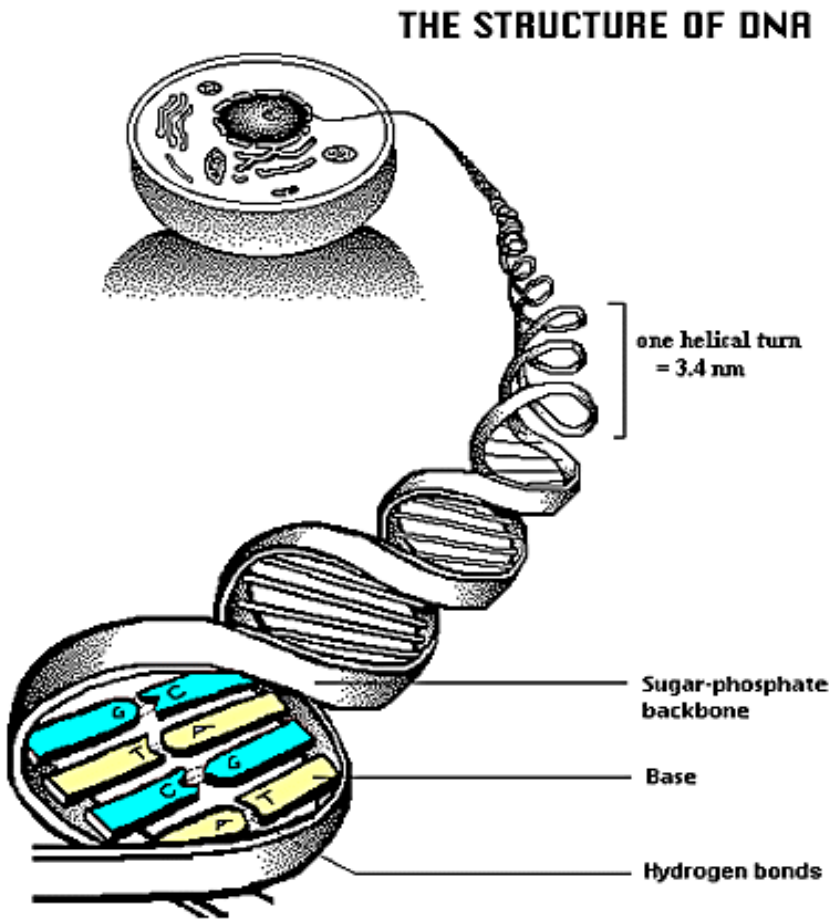
Genes are linearly arranged along chromosomes



Genes

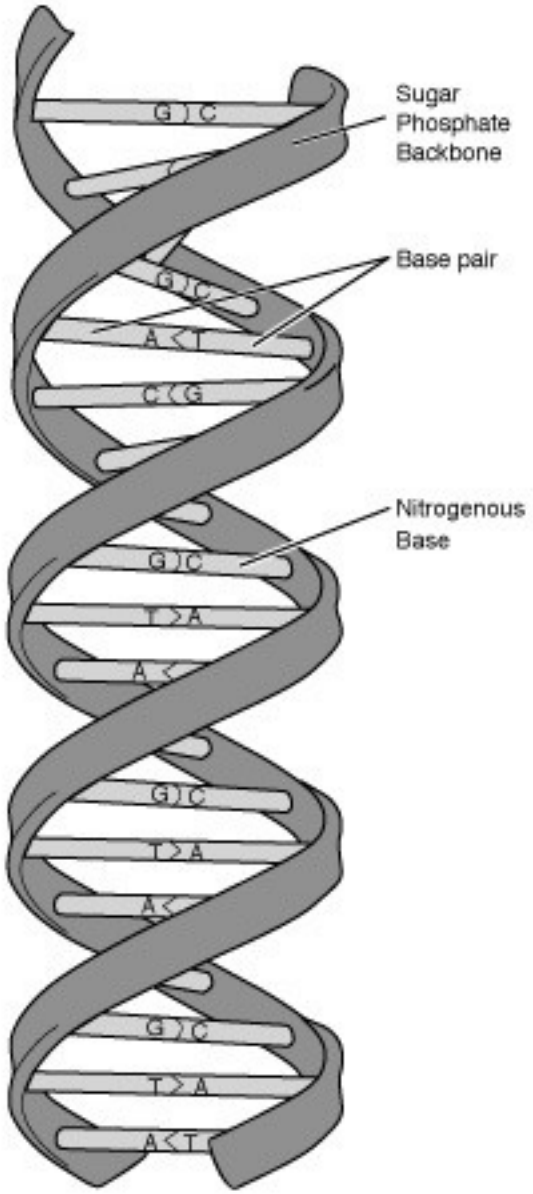


DNA can be simplified to a string of four letters

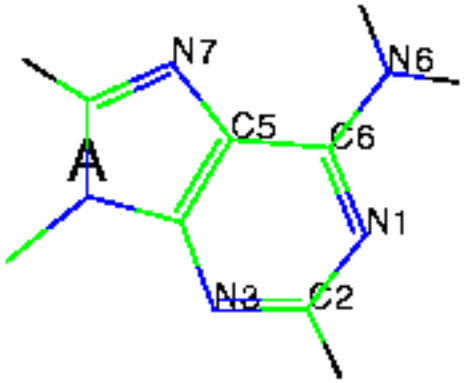


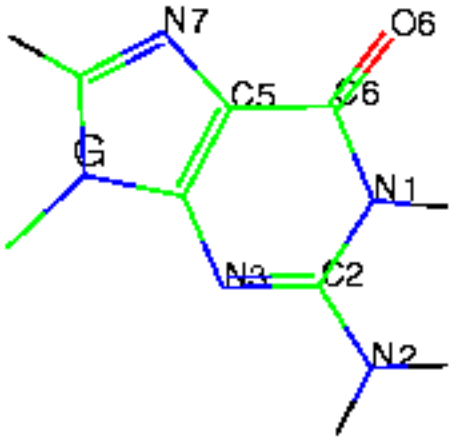
GATTACA

DNA Structure (overview)

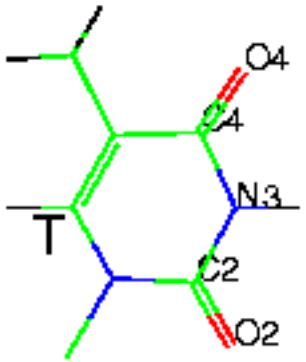


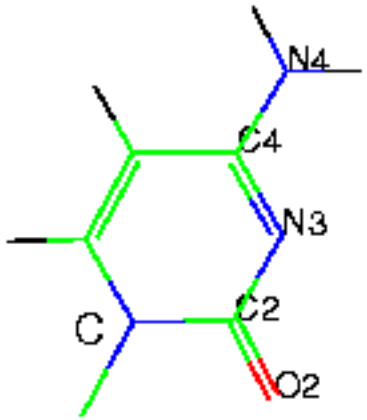
Nucleotide Bases

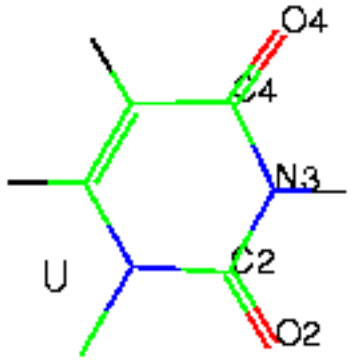




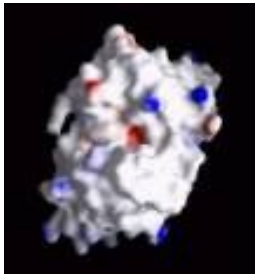
Adenine (A) Guanine (G) (Purines)







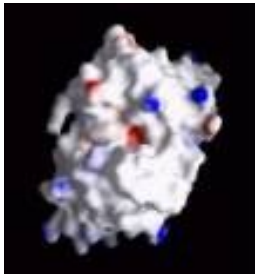
Thymine (T) (DNA) (Pyrimidines) Cytosine (C) Uracil (U) (RNA)



Genomic Nucleotide Composition

Sequence	Locus Name*	Base A	C	G	T	Total
Bacteriophages						
Lambda	*LAMCG*	0.25	0.24	0.25	0.26	48502
T7	*PT7*	0.27	0.23	0.24	0.26	39936
ϕX174	*PX1CG*	0.24	0.22	0.31	0.23	5386
Viruses						
Cauliflower mosaic	*MCACGDH*	0.37	0.21	0.23	0.19	8016
Human papovirus BK	*PVBMM*	0.30	0.20	0.30	0.20	4963
Hepatitis B	*HPBAYW*	0.28	0.22	0.23	0.27	3182
Mitochondria						
Human	*HUMMT*	0.31	0.31	0.25	0.13	16569
Bovine	*BOVMT*	0.33	0.26	0.27	0.14	16338
Mouse	*MUSMT*	0.35	0.24	0.29	0.12	16295

* Names in GenBank database.



DNA Reading Frames

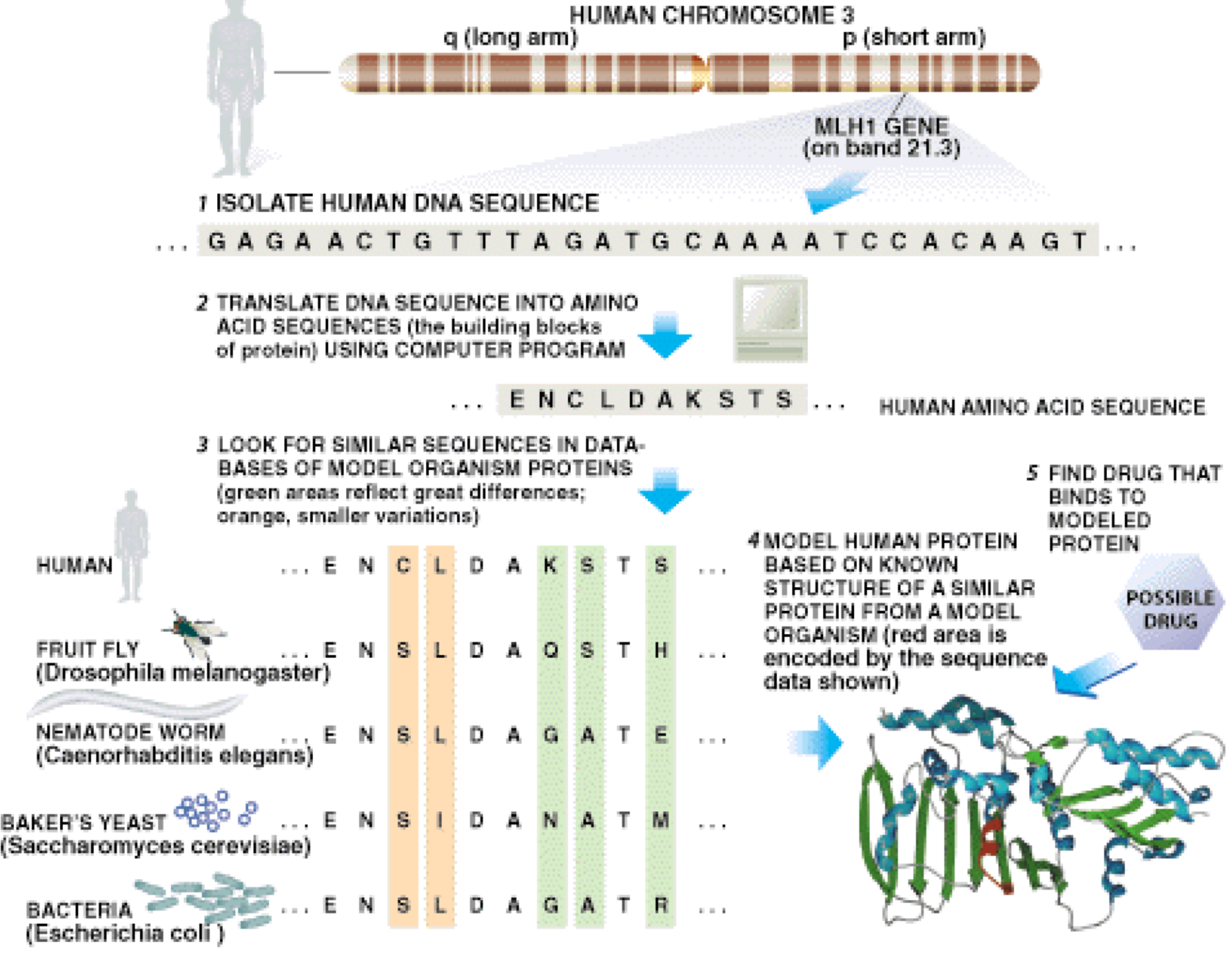
AGCTACGTAGCTAGCTA

AGCTACGTAGCTAGCTA

A**GCTACGTAGCTAGCT**A

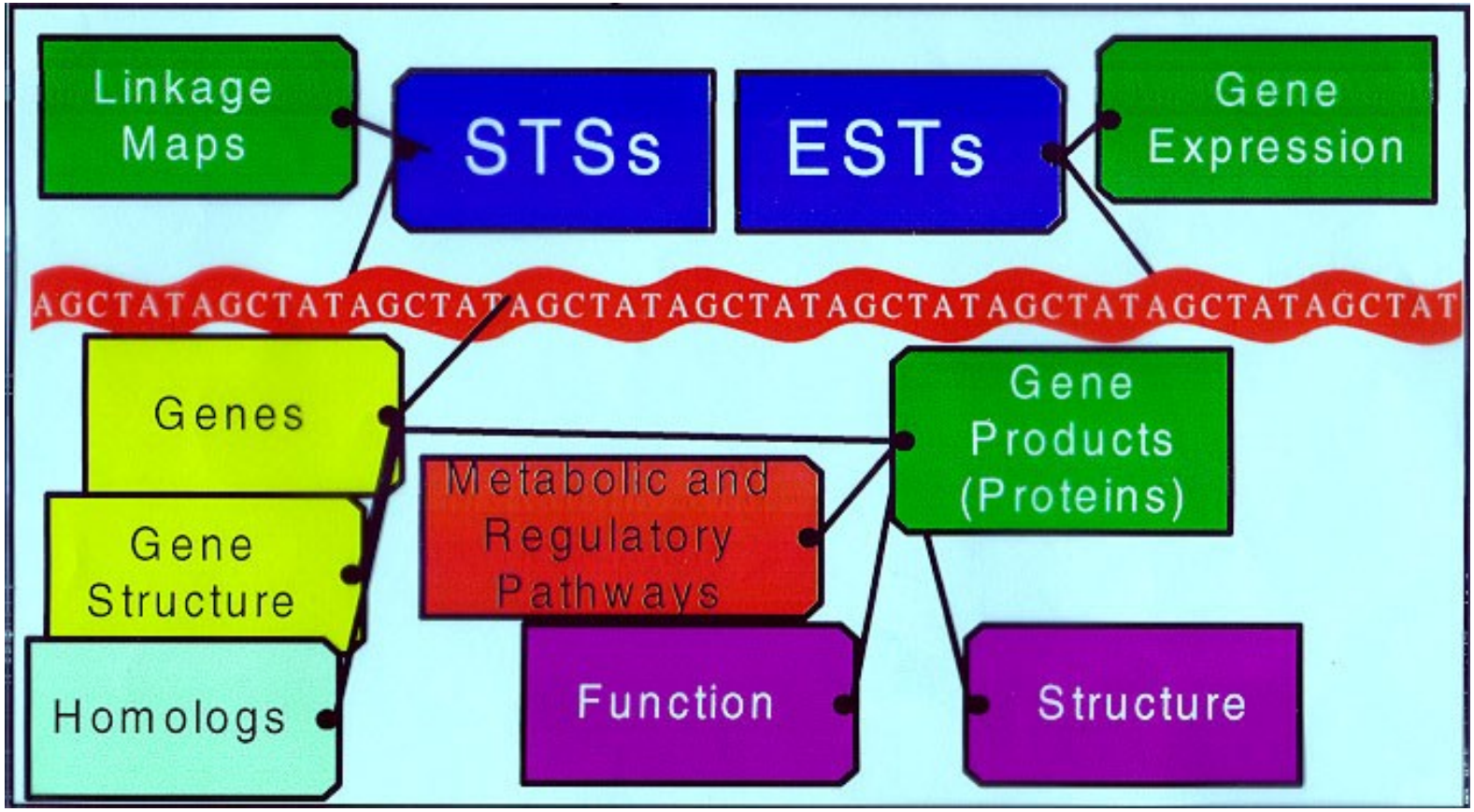
AG**CTACGTAGCTAG**CTA

mRNA has only **three** reading frames, whereas dsDNA has **six**!


HUMAN CHROMOSOME 3
q (long arm)
p (short arm)
MLH1 GENE
(on band 21.3)
1 ISOLATE HUMAN DNA SEQUENCE
. . . G A G A A C T G T T A G A T G C A A A A T C C A C A A G T . . .
2 TRANSLATE DNA SEQUENCE INTO AMINO ACID SEQUENCES (the building blocks of protein) USING COMPUTER PROGRAM
. . . E N C L D A K S T S . . .
HUMAN AMINO ACID SEQUENCE
3 LOOK FOR SIMILAR SEQUENCES IN DATA-BASES OF MODEL ORGANISM PROTEINS (green areas reflect great differences; orange, smaller variations)
HUMAN . . . E N C L D A K S T S . . .
FRUIT FLY (Drosophila melanogaster) . . . E N S L D A Q S T H . . .
NEMATODE WORM (Caenorhabditis elegans) . . . E N S L D A G A T E . . .
BAKER'S YEAST (Saccharomyces cerevisiae) . . . E N S I D A N A T M . . .
BACTERIA (Escherichia coli) . . . E N S L D A G A T R . . .
4 MODEL HUMAN PROTEIN BASED ON KNOWN STRUCTURE OF A SIMILAR PROTEIN FROM A MODEL ORGANISM (red area is encoded by the sequence data shown)
5 FIND DRUG THAT BINDS TO MODELED PROTEIN
POSSIBLE DRUG

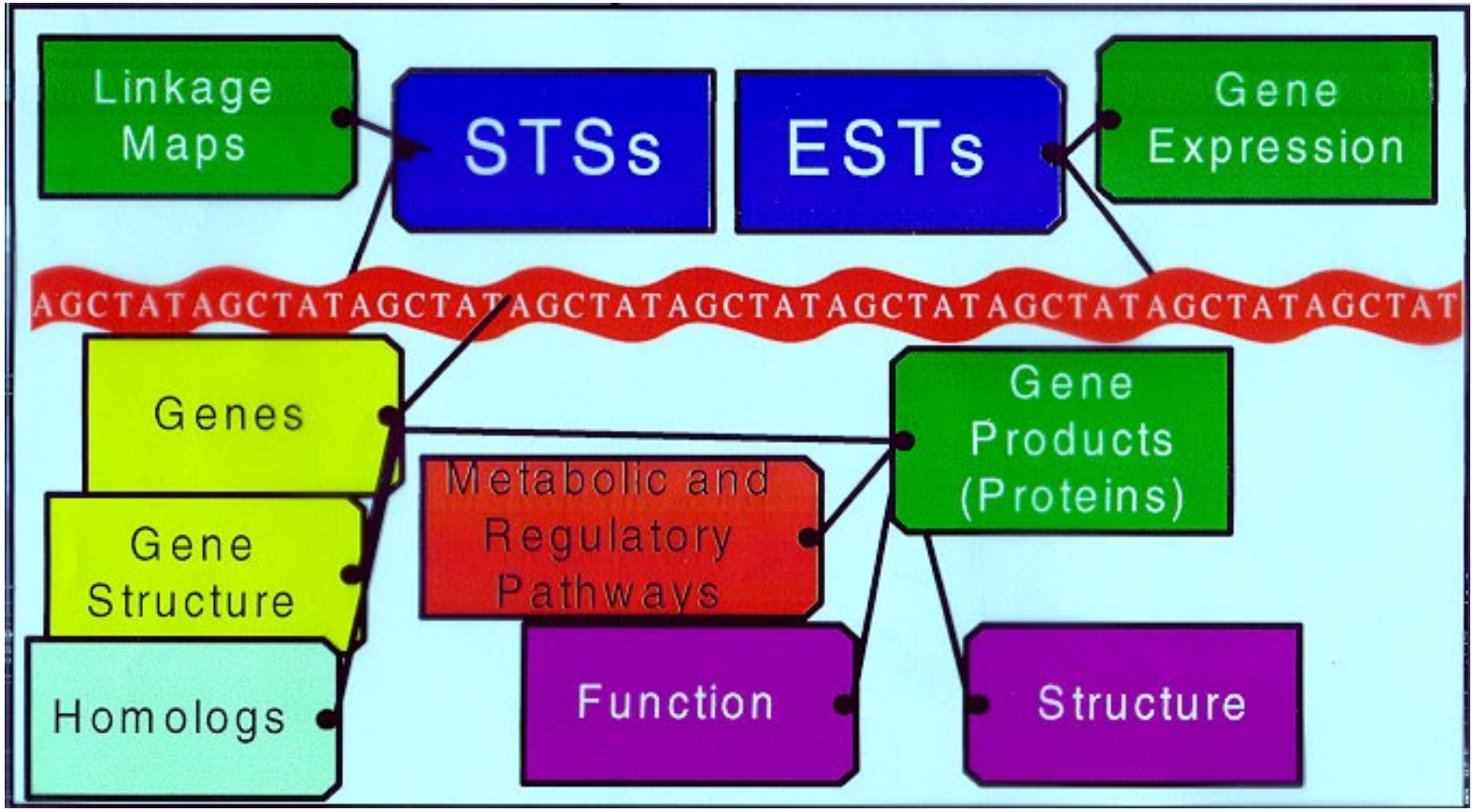
Genome Annotation

The Process of Adding Biology Information and Predictions to a Sequenced Genome Framework

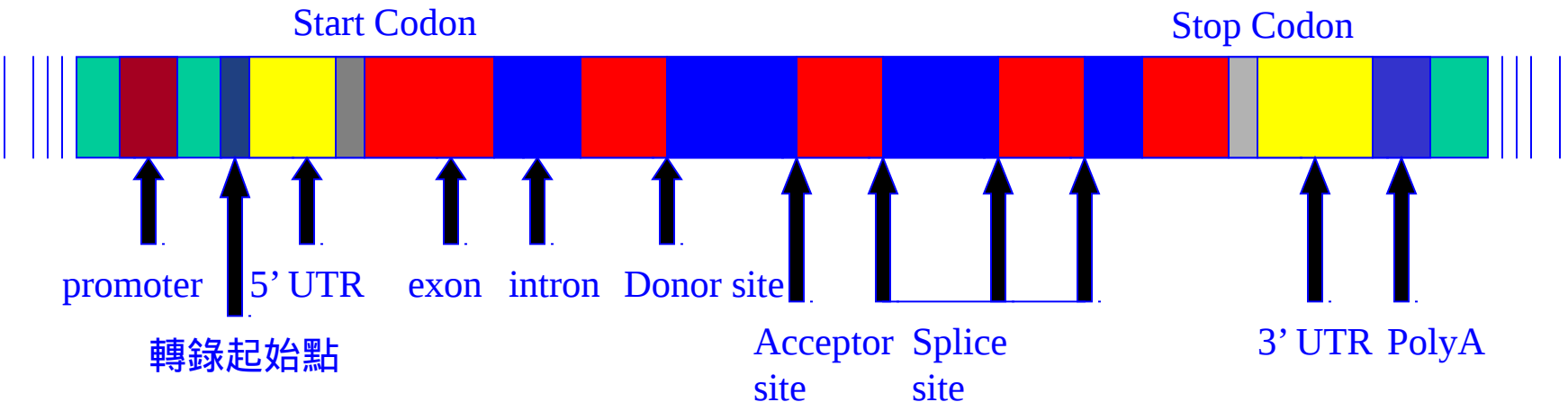


Genome Annotation

The Process of Adding Biology Information and Predictions to a Sequenced Genome Framework



DNA intron-exon structure

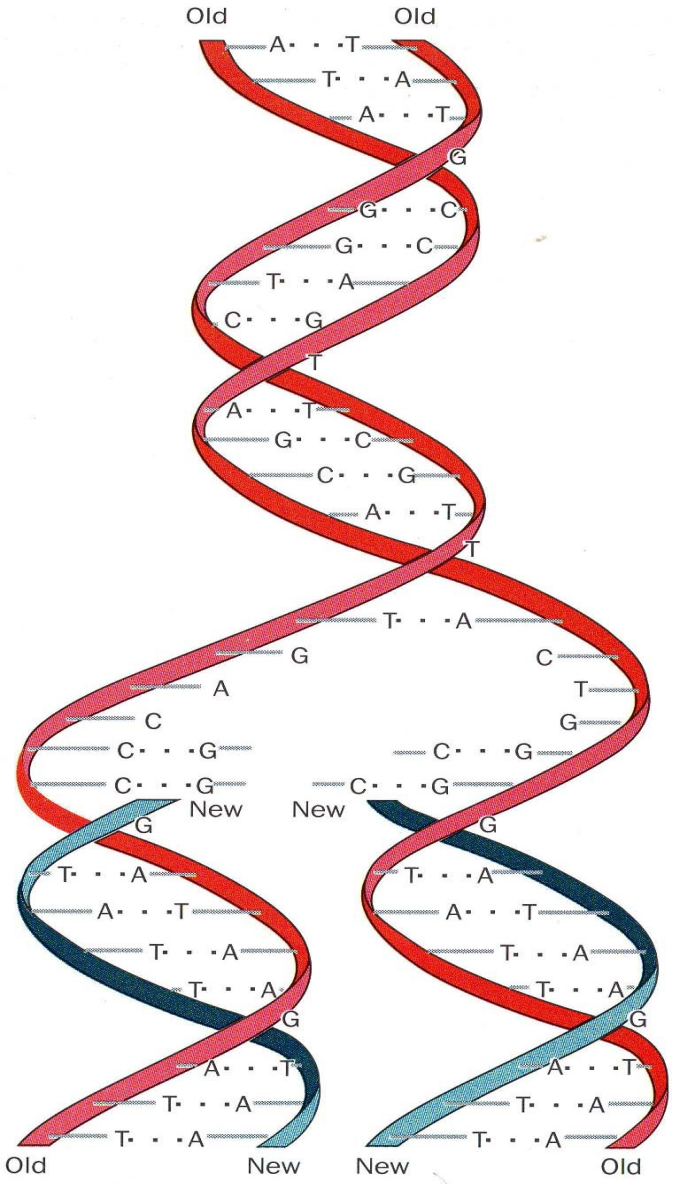


Nucleotide codes

A	Adenine	W	Weak (A or T)
G	Guanine	S	Strong (G or C)
C	Cytosine	M	Amino (A or C)
T	Thymine	K	Keto (G or T)
U	Uracil	B	Not A (G or C or T)
R	Purine (A or G)	H	Not G (A or C or T)
Y	Pyrimidine (C or T)	D	Not C (A or G or T)
N	Any nucleotide	V	Not T (A or G or C)

DNA Replication

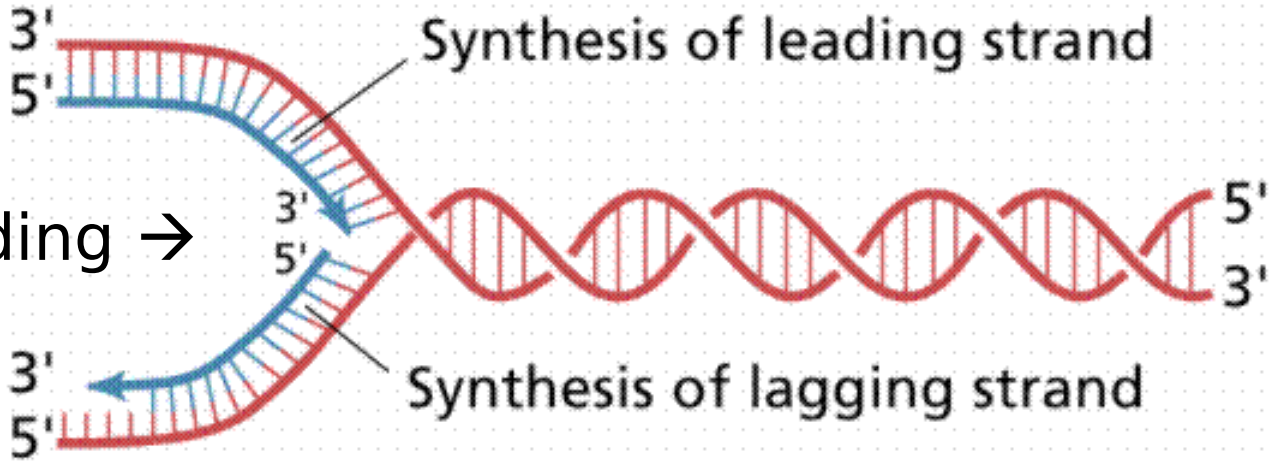
- The DNA strand that is copied to form a new strand is called a template
- In the replication of a double-stranded or duplex DNA molecule, both original (parental) DNA strands are copied
- When copying is finished, the two new duplexes, each consisting of one of the original strands plus its copy, separate from each other (semiconservative replication)

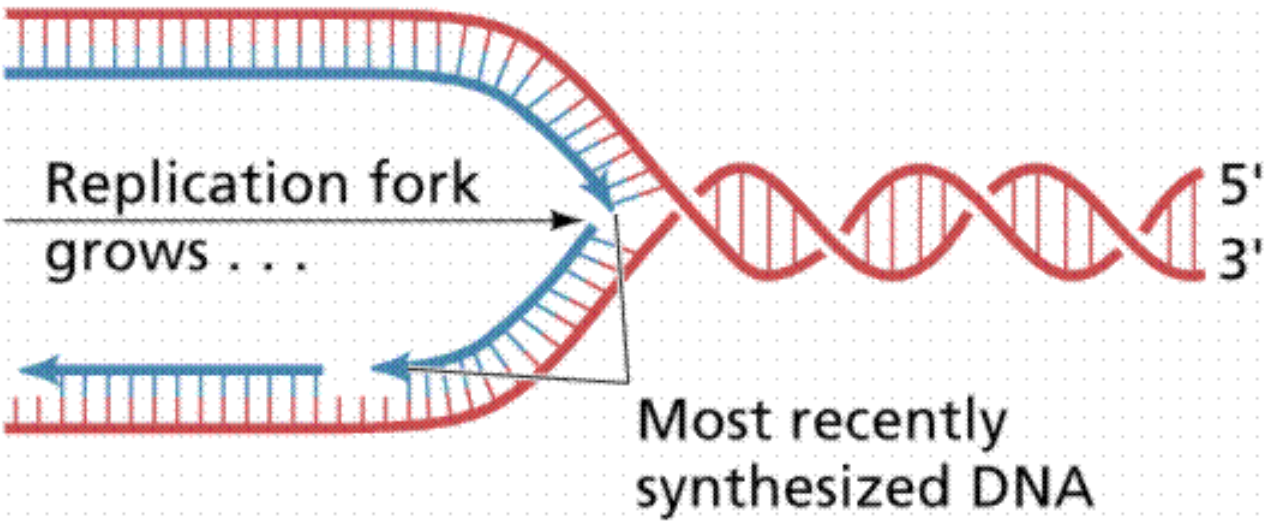


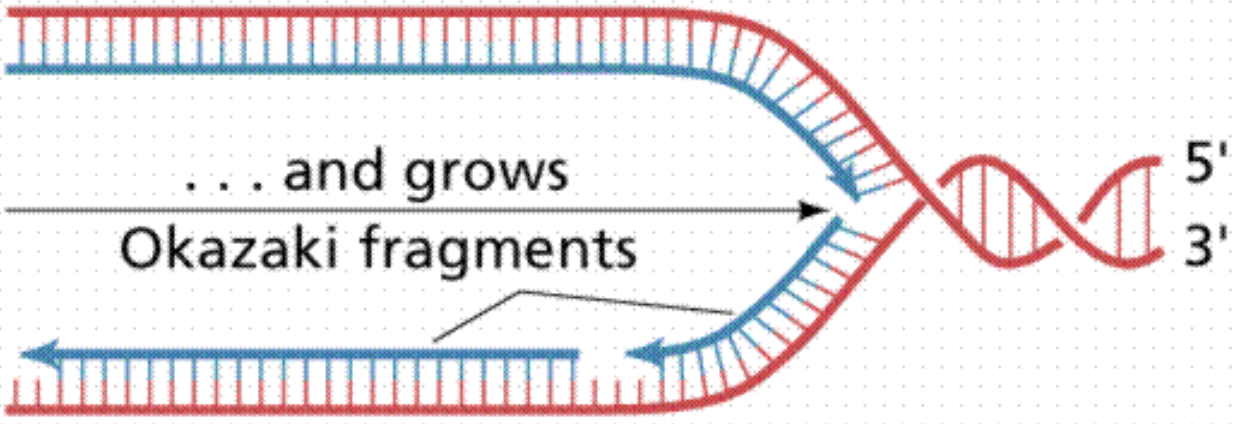
Schematic diagram of DNA replication.

DNA Synthesis

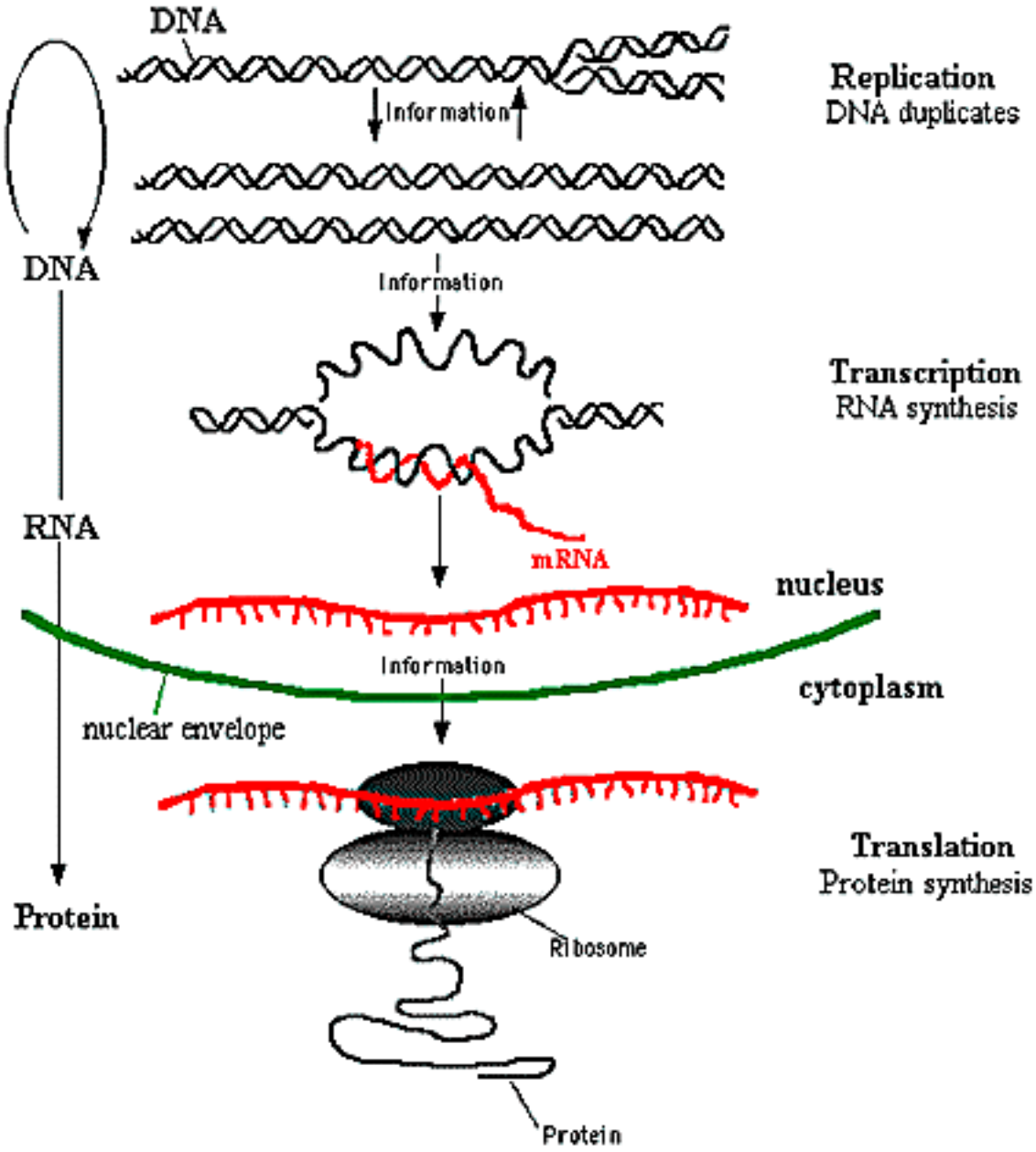
DNA is unwinding →




Replication fork
grows . . .
5'
3'
Most recently
synthesized DNA

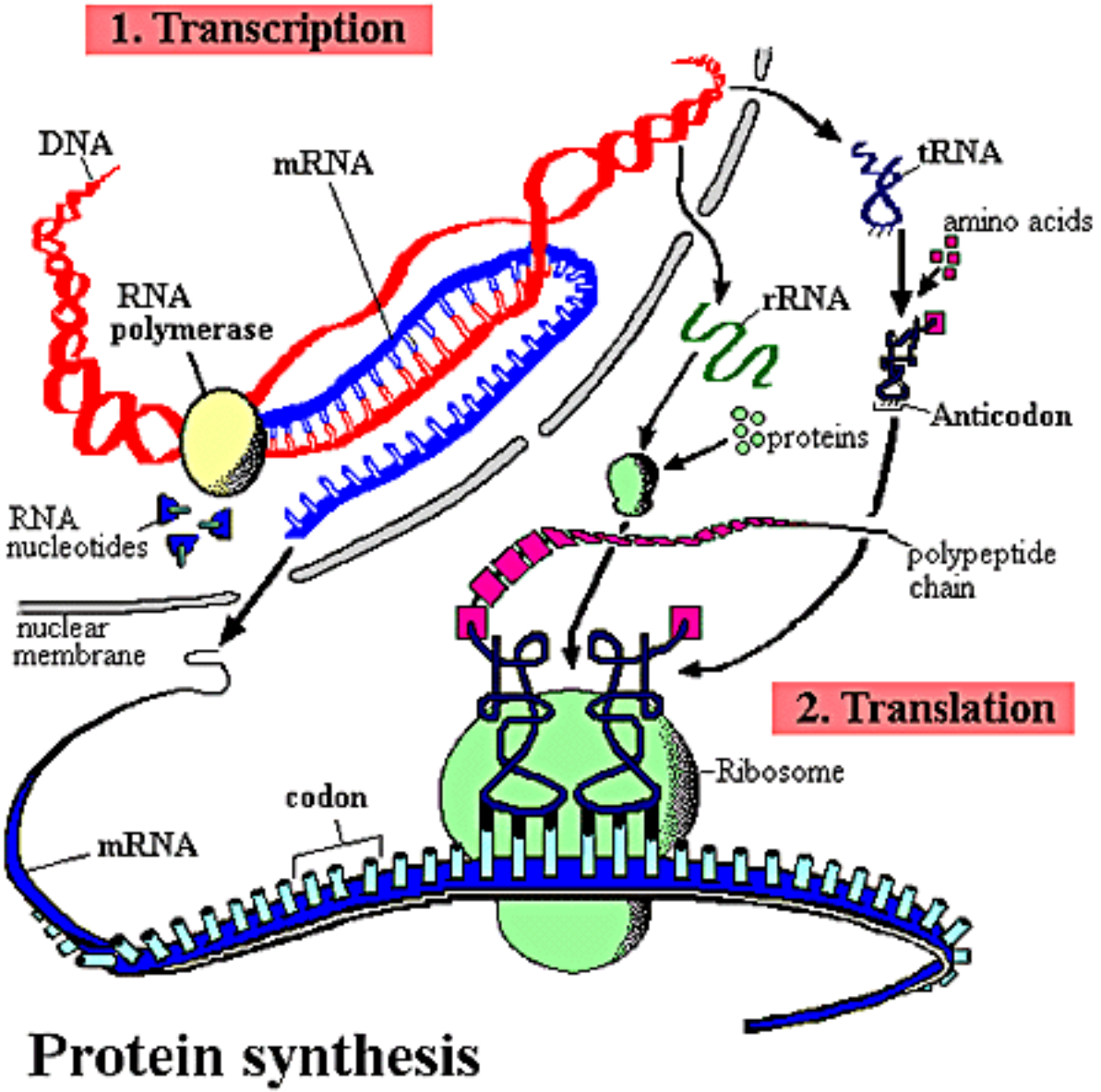

. . . and grows
Okazaki fragments
5'
3'

(RT)



The Central Dogma of Molecular Biology

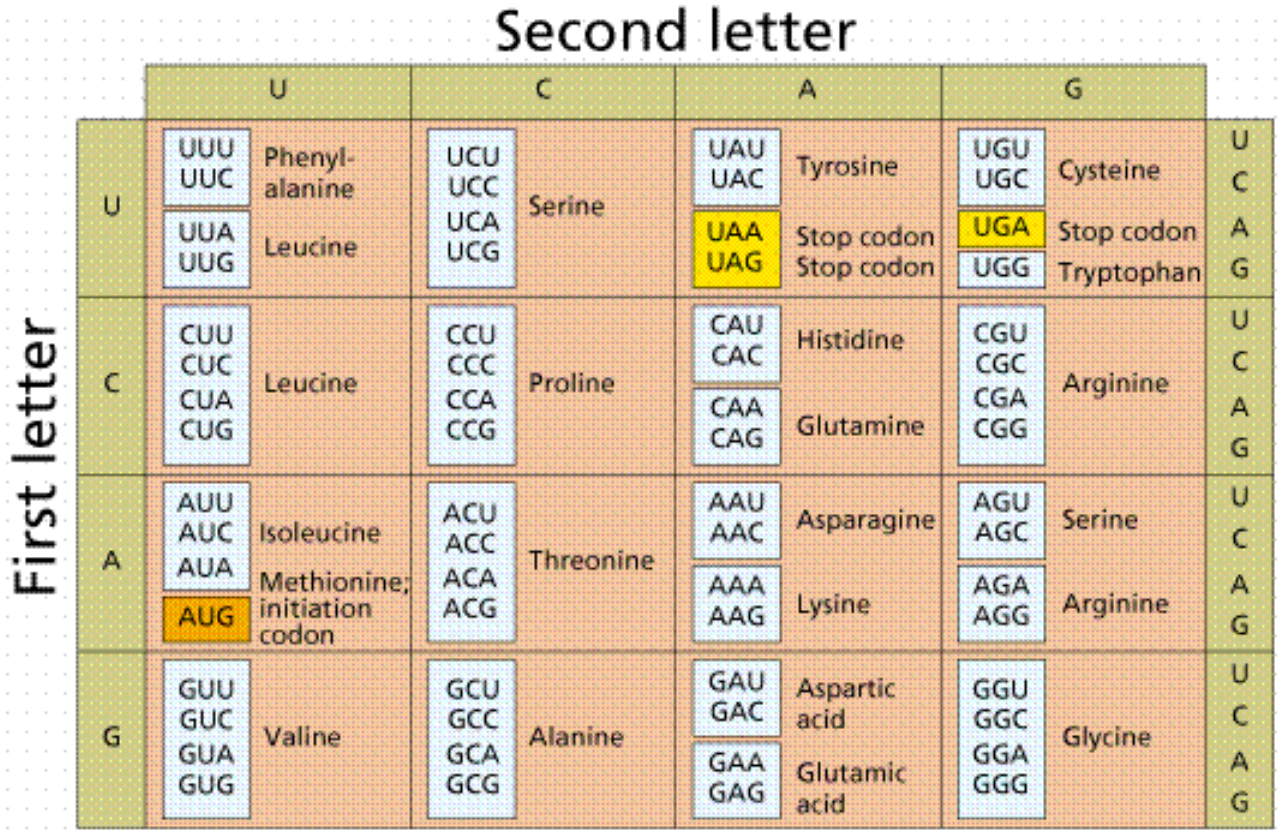
Protein Synthesis



Proteins

- Proteins: macromolecules composed of one or more chains of amino acids
- Amino acids: class of 20 different organic compounds containing a basic amino group (-NH_2) and an acidic carboxyl group (-COOH)
- The order of amino acids is determined by the base sequence of nucleotides in the gene coding for the protein
- Proteins function as enzymes, antibodies, structures, etc.

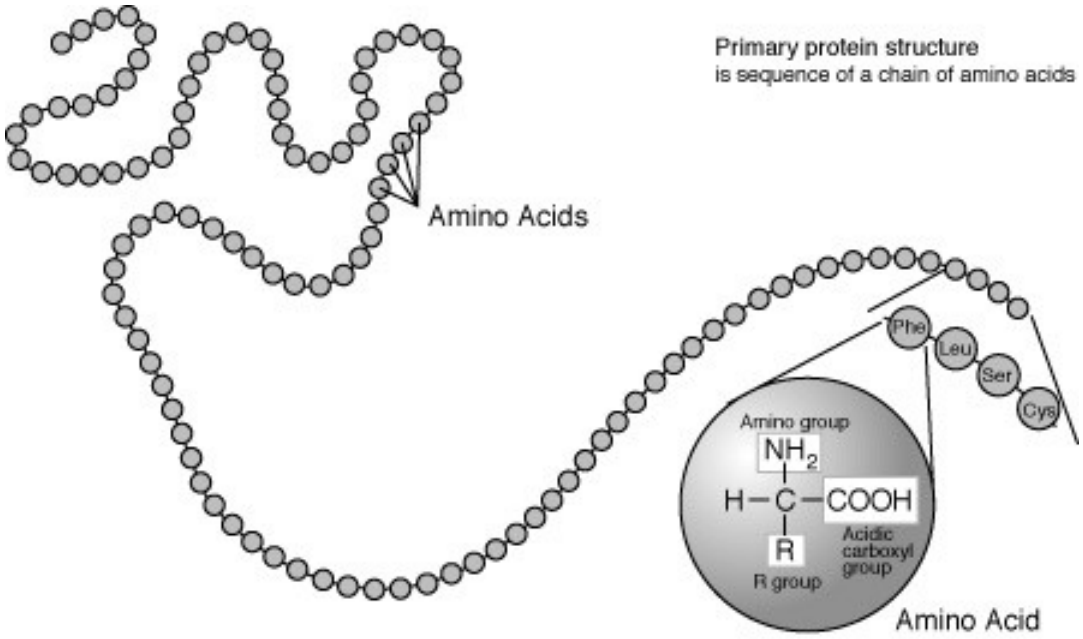
Standard Genetic Code



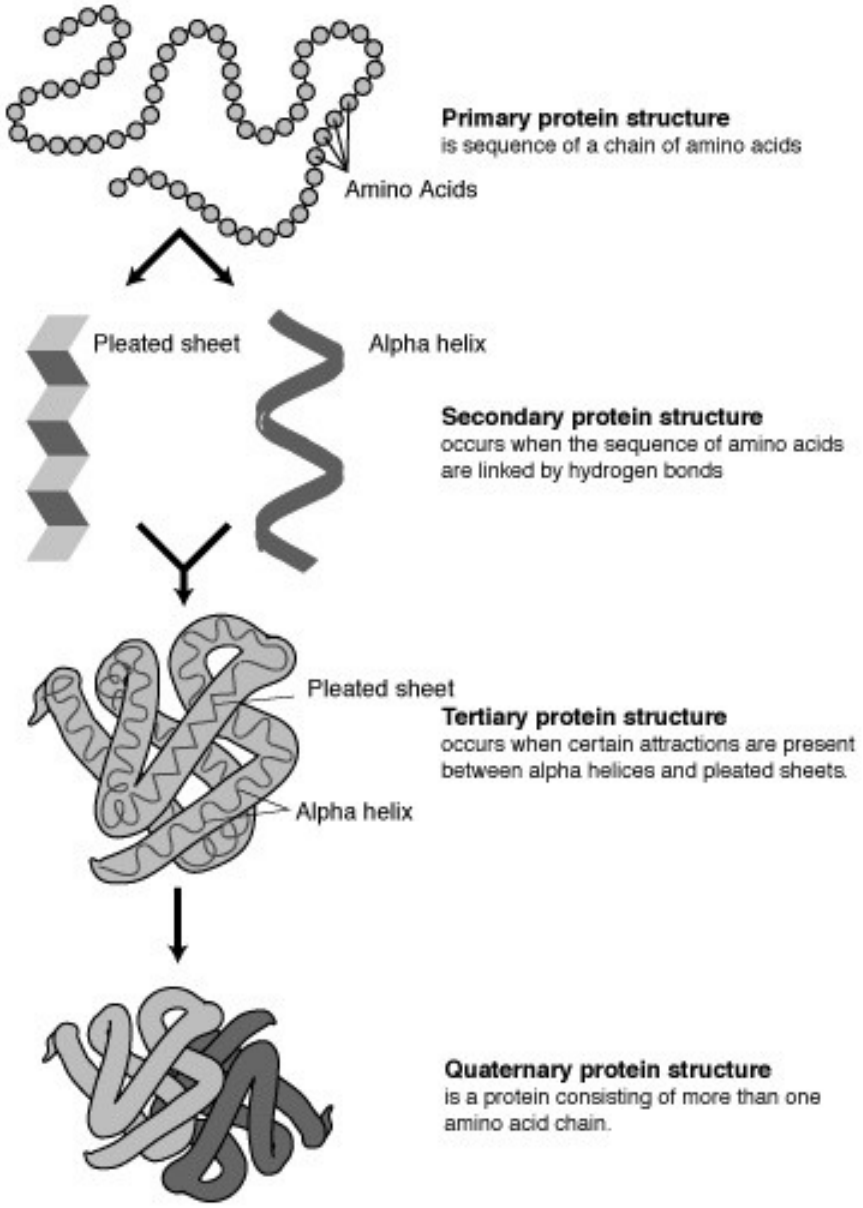
Amino acid codes

Ala	A	Alanine
Arg	R	Arginine
Asn	N	Asparagine
Asp	D	Aspartic acid
Cys	C	Cysteine
Gln	Q	Glutamine
Glu	E	Glutamic acid
Gly	G	Glycine
His	H	Histidine
Ile	I	Isoleucine
Leu	L	Leucine
Lys	K	Lysine
Met	M	Methionine
Phe	F	Phenylalanine
Pro	P	Proline
Ser	S	Serine
Thr	T	Threonine
Trp	W	Tryptophan
Tyr	Y	Tyrosine
Val	V	Valine
Asx	B	Asn or Asp
Glx	Z	Gln or Glu
Sec	U	Selenocysteine
Unk	X	Unknown

Primary Protein Structure

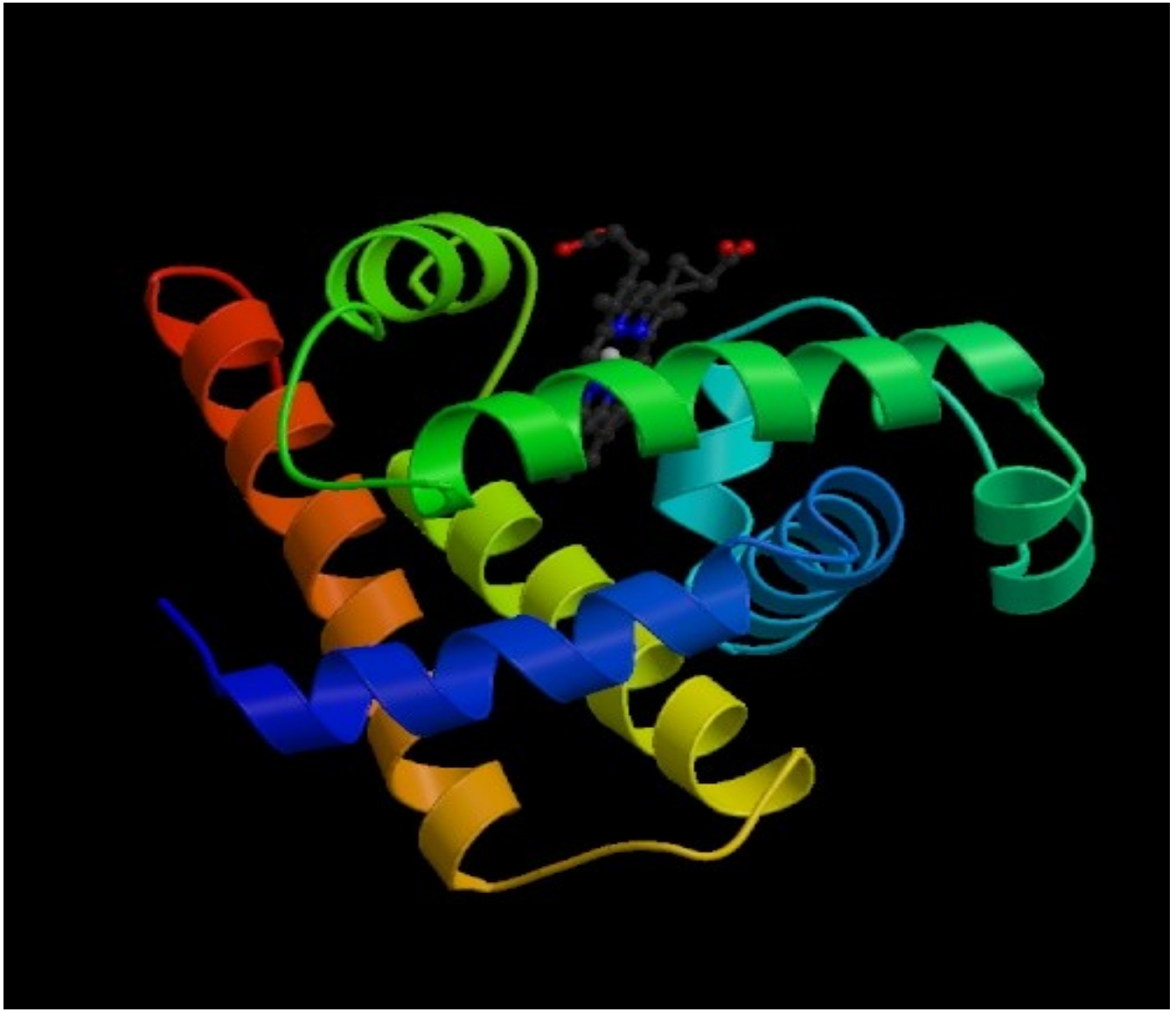


Multiple Levels of Protein Strucure



(← Protein folding)

Tertiary Structure of Sperm whale myoglobin (1MBN)



Sequence to Structure: It's a matter of dimensions!

- 1D Nucleic acid sequence

AGT-TTC-CCA-GGG…

- 1D Protein sequence

Met-Ala-Gly-Lys-His…
M – A – G – K – H…

- 3D Spatial arrangement of atoms