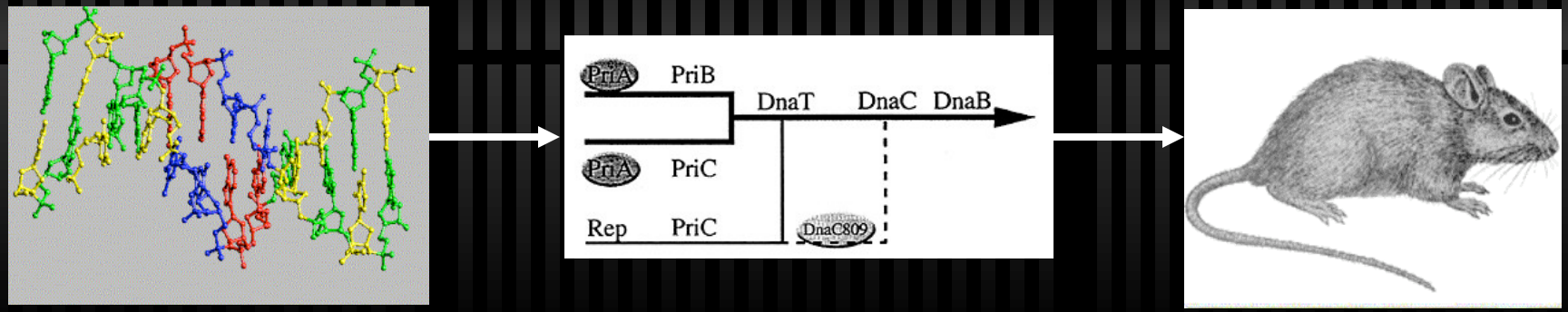
Topics in Bio-Signal Processing

From an EE perspective

Professor Gail L. Rosen



Course Website

- ✓ http://www.ece.drexel.edu/gailr/ECE-S690-503/

Deliverables

- Approx. 5 Homeworks (mini-projects)
- Literature Review and two-page project proposals – April 28th (Presentations)
- 1-page Project Updates: May 19th
- Final Projects -- June 9th

April 15th

Dr. Itsik Pe'er I Assistant Professor in the Computer Science, Columbia University

Title: Human Genetics

Date: April 15th

Time: 5:00 pm

Location: CRB Austrian Auditorium

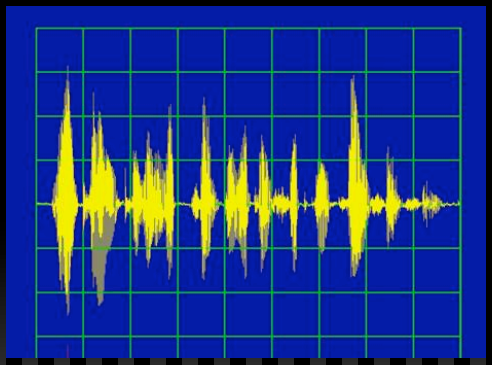
(Once a month - Penn Bioinformatics Forum)

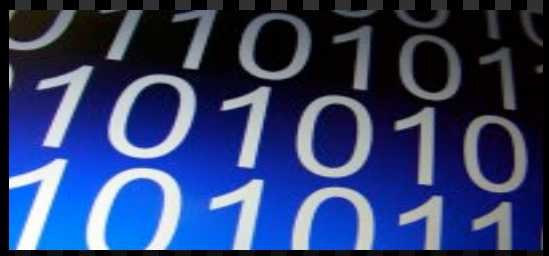
http://www.pcbi.upenn.edu/forum.php

What are bio-signals?

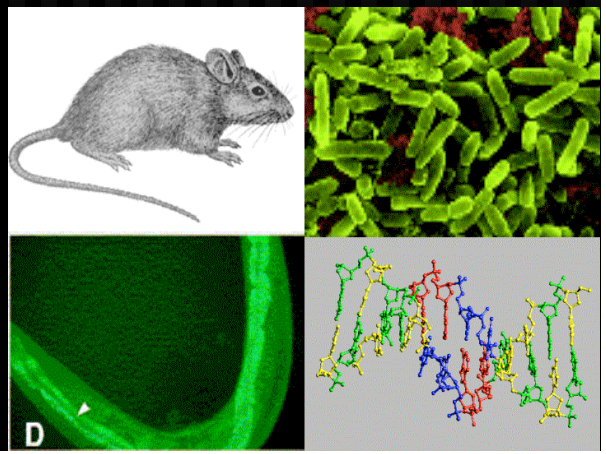
What is Bio-Signal Processing?

- **Digital Signal Processing:**
  Processing/Analysis of digitized signals
- **Genomic Signal Processing:**
  Signals are DNA



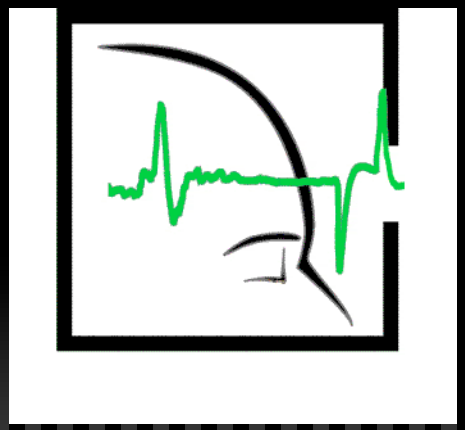


- **Biological Signal Processing:**
  Signals are DNA, protein amounts, protein movement

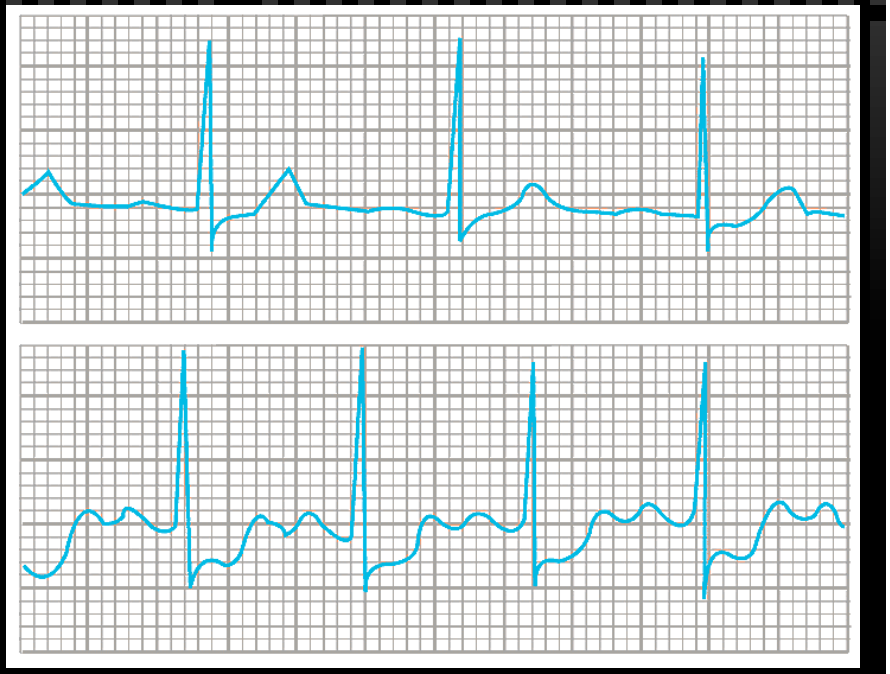


Others types of bio-signals, not covered

- EEG, ECG



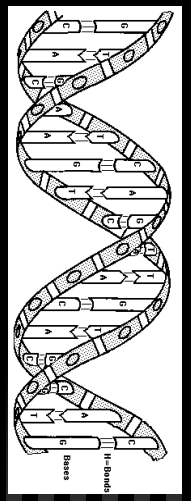
- Cell Signaling



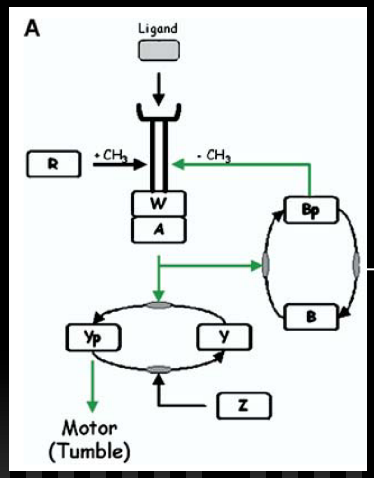
Why electrical engineering for biology?

Electrical Engineering for Biology?

Biological System



DNA



Protein Pathways

Function

Engineered System

Model

Signal Processing

Algorithm

System Computation

Performance

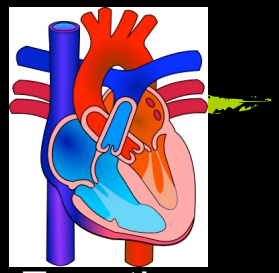
Implementation

Classic SP for Biology Applications

- ✓ Most Popular: Speech Signal Processing
- ✓ Pattern Recognition / Hidden Markov Models: Aligning sequences, classifying similar genes, gene prediction
- ✓ Boolean Networks: Modeling Genetic Regulatory Networks

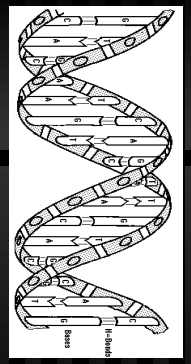
How have we historically looked at Biology?

Historical Understanding of Biology



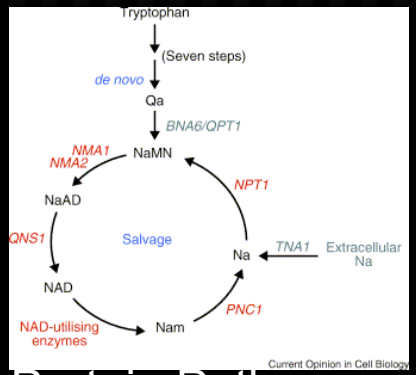
Function

Beginnings of Medicine: 2000 B.C. (Asia), 500 B.C. (Hippocrates)



DNA

Discovery of DNA: 1950 (Wilkins and Franklin), 1953 (Watson and Crick)



Protein Pathways

Feedback Regulation in Metabolism: 1957 (Umbarger, Brown) (Yates, Pardee)
1970's: major breakthroughs

Syllabus Highlights

- Literature Review and Project Proposal (Due Feb. 6)
  - Start thinking about a topic (please feel free to meet with me).
  - Schedule meetings with me to check feasibility of topic.
- Final Project -- Exploratory research project for YOU to learn about the State-of-the-Art in the field (Due. March 19th).

Today's Topics

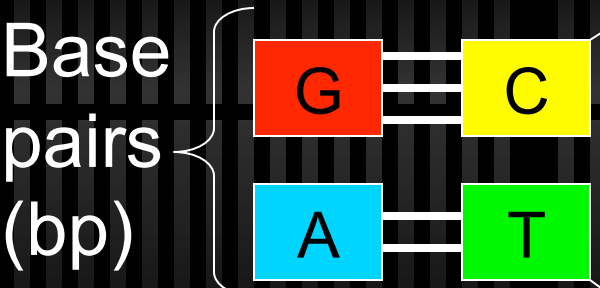
- ✓ Introduction to DNA, Molecular Biology, and the challenges
- ✓ Tools -- Use of Genbank
- ✓ Challenges in the field
- ✓ Hands-on Databases

DNA Structure

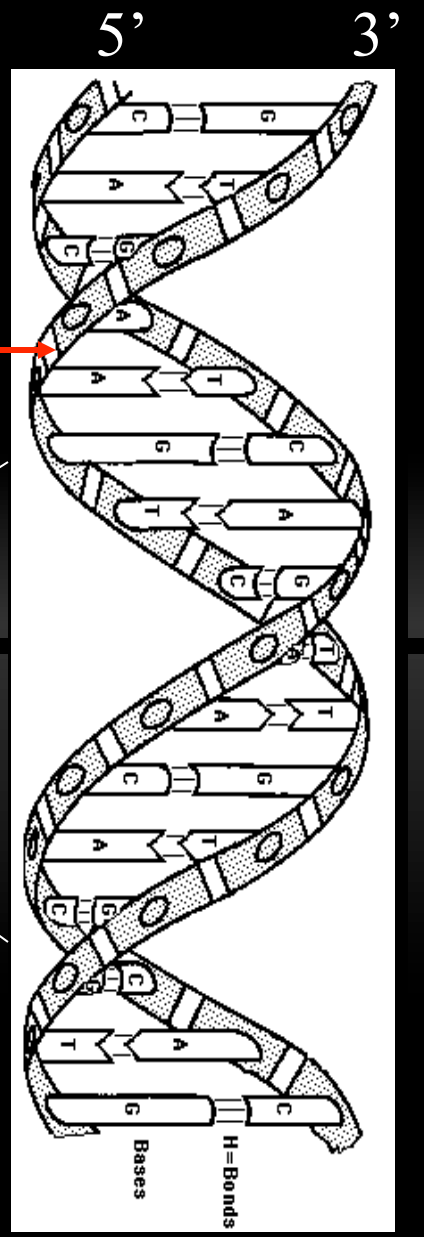
- ✓ 4 Nucleotides (bases)
- ✓ 3 Bonds for G-C
- ✓ 2 Bonds for A-T
- ✓ Helical twist

Phosphate Backbone

Base pairs (bp)

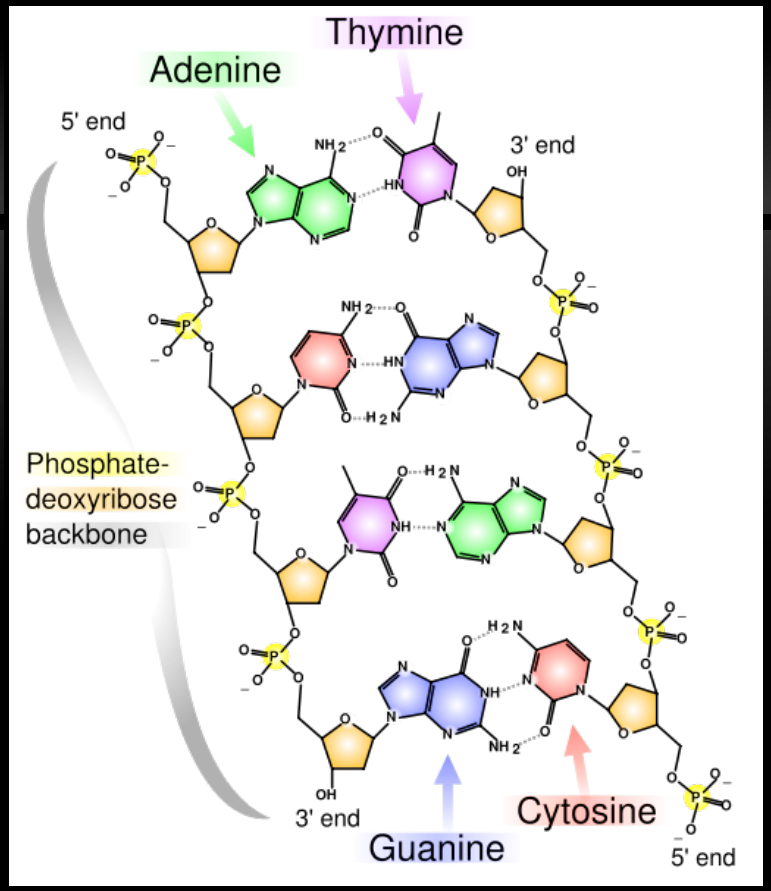


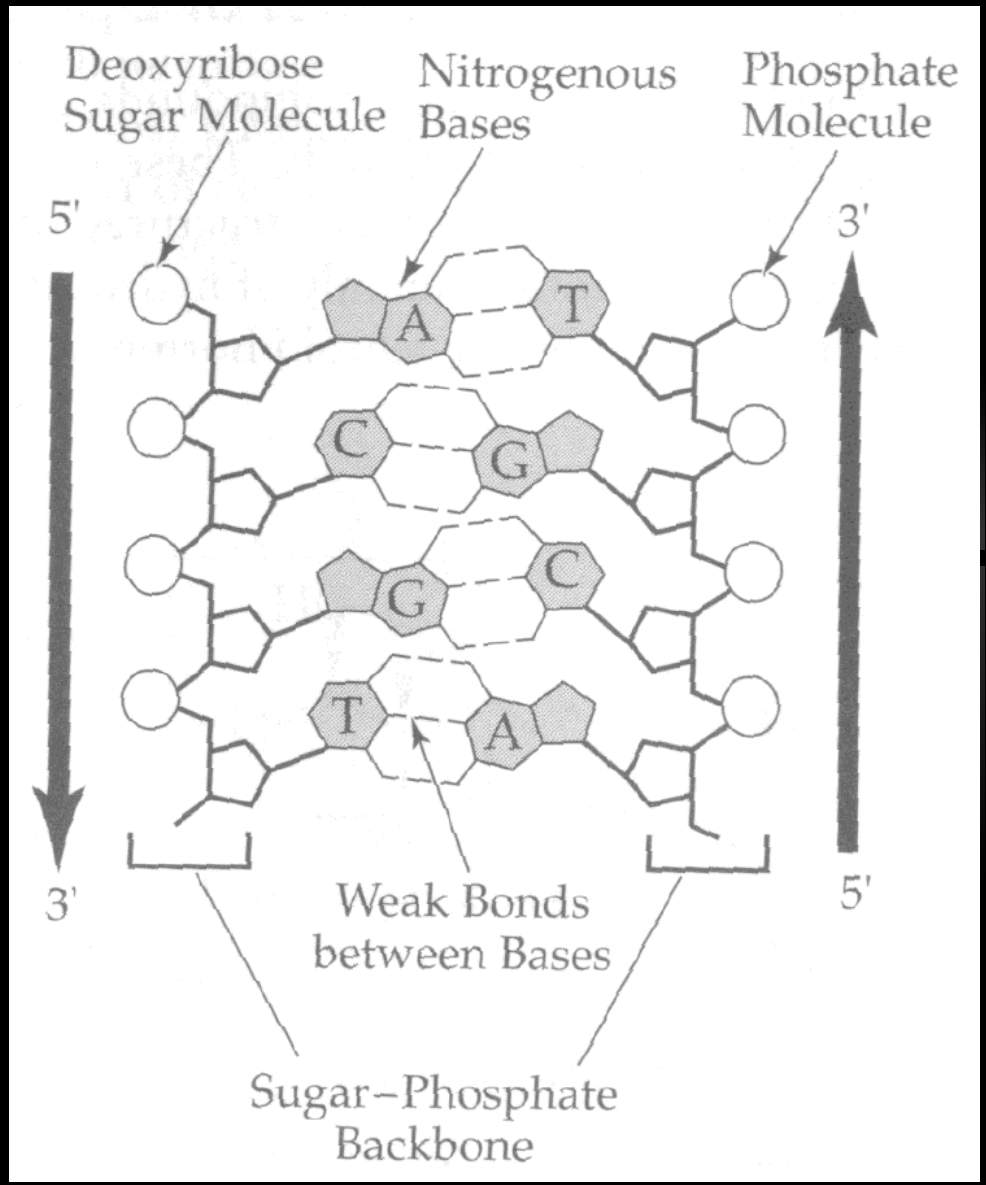
1953



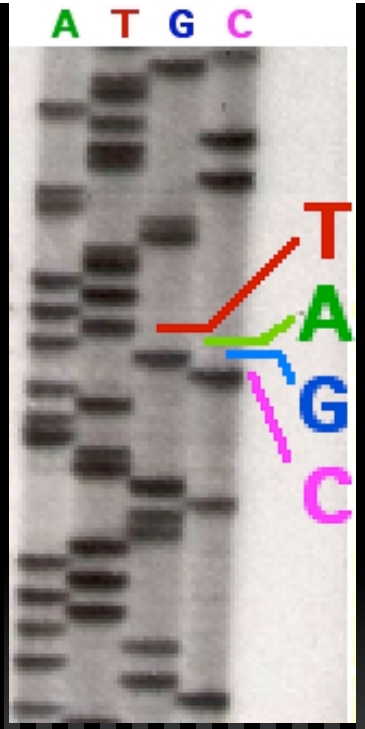
Directional Reading

Third (3') and Fifth(5') Carbon Atoms in Sugar ring.





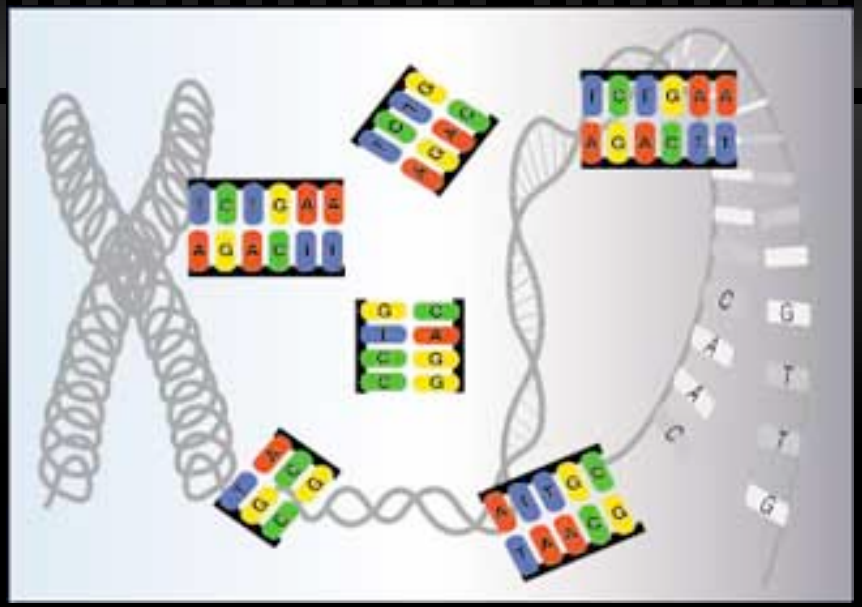
Sequencing



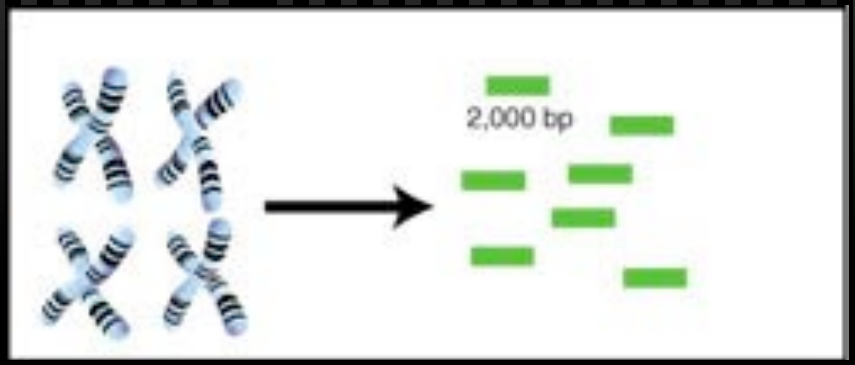
- ✓ Classic: Radioactive Primer labeling
- ✓ Revolutionary: Shot-gun sequencing (consensus of random segments)
- ✓ Errors in base-calling! (1 in 10K)
- ✓ Databases have errors!

Sequencing

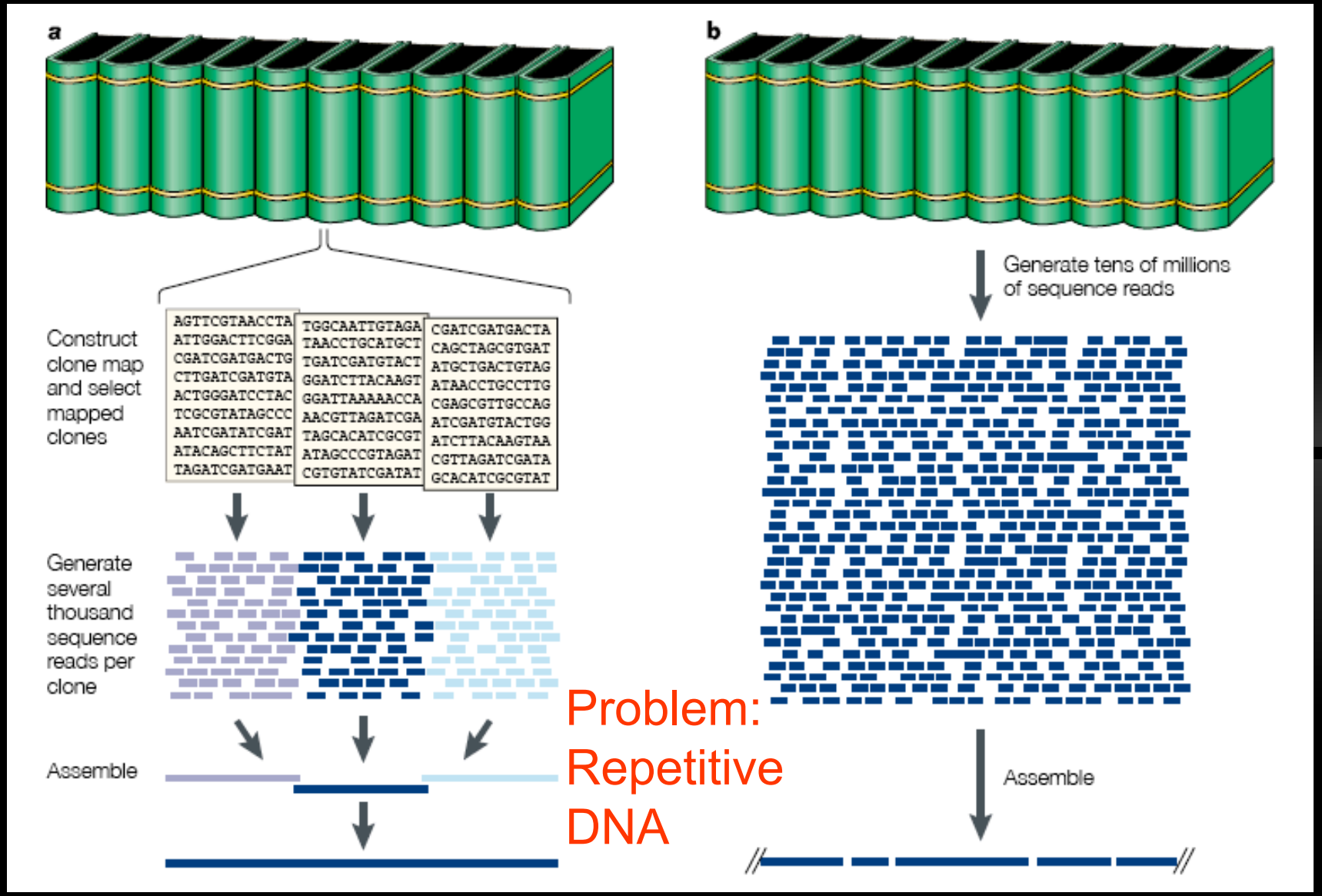
- Given a set of overlapping sequences, randomly sampled from a target, reconstruct the order and position of those sequences



Can only do small fragments



Sequencing methods



Electropheresis -- base calling using weights of molecule

Consensus: Averaging out the base-calling errors

Sanger Method

- http://www.youtube.com/watch?v=oYpllbI0qF8

Pyrosequencing

- http://www.youtube.com/watch?v=kYAGFrbGI6E

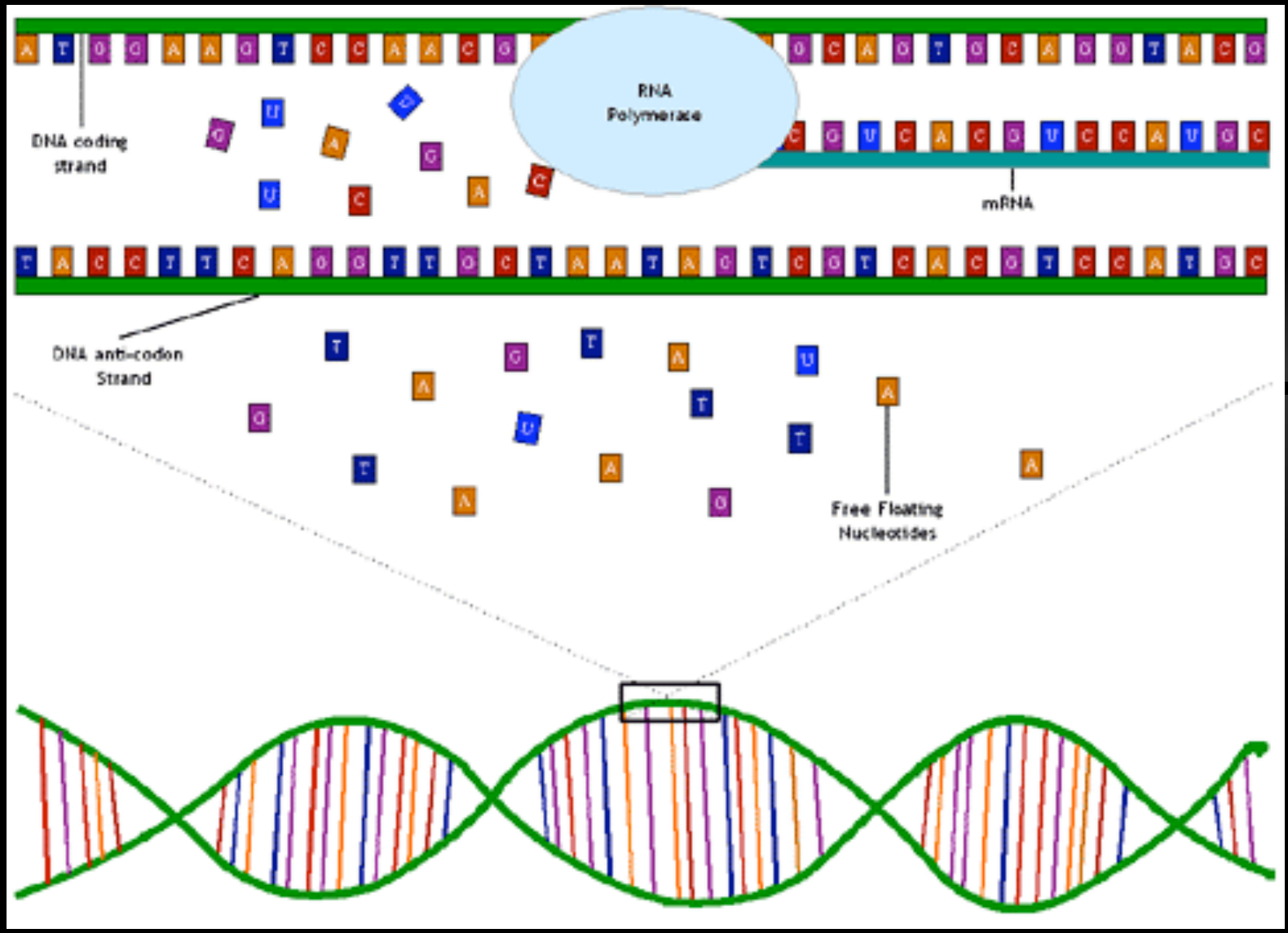
We have the bases -- now what?

- ✓ What is a gene?

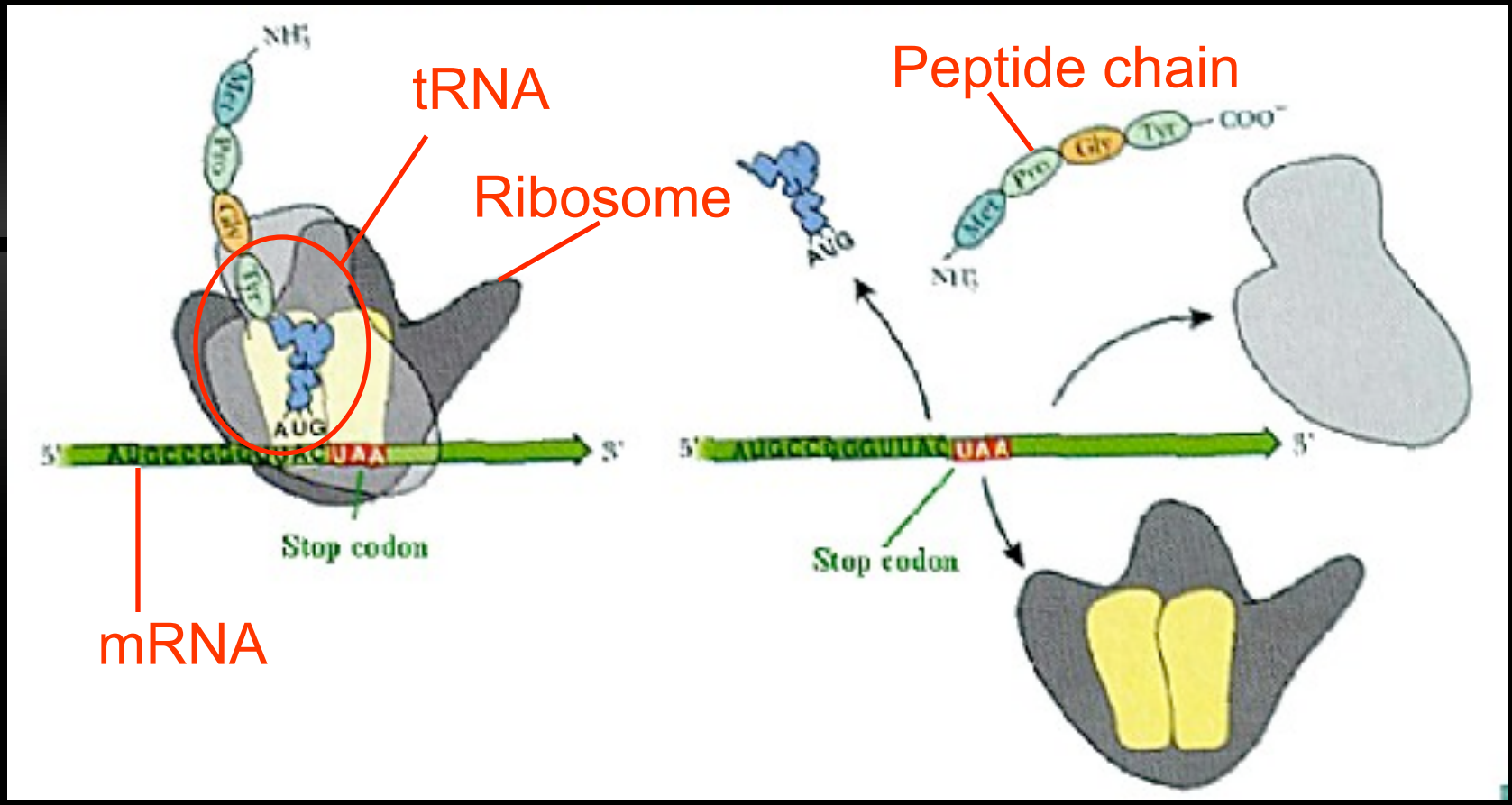
Genetic Code

- Marshall Nirnberg (60's) discovers the genetic code
- 3 nucleotides produc one amino acid

Transcription



Translation



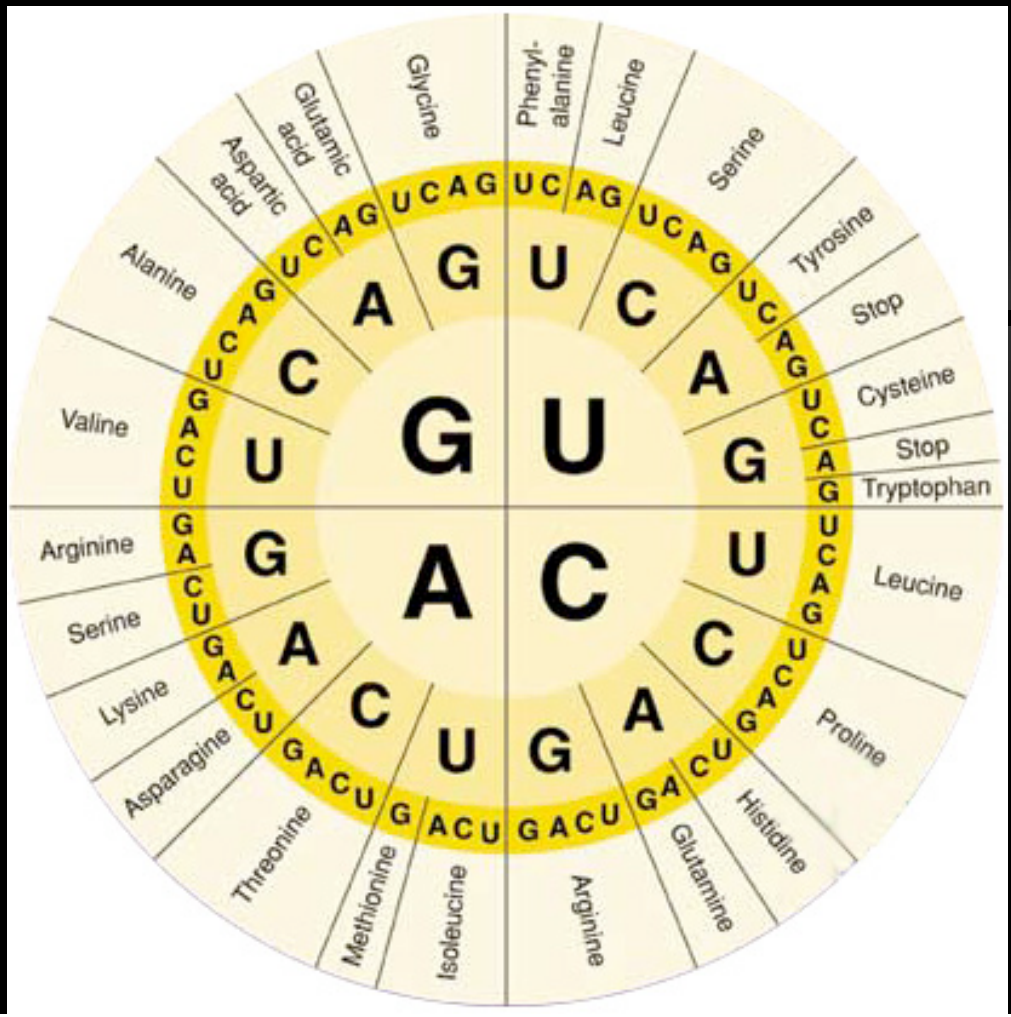
Standard Genetic Code

64 Codons map to:

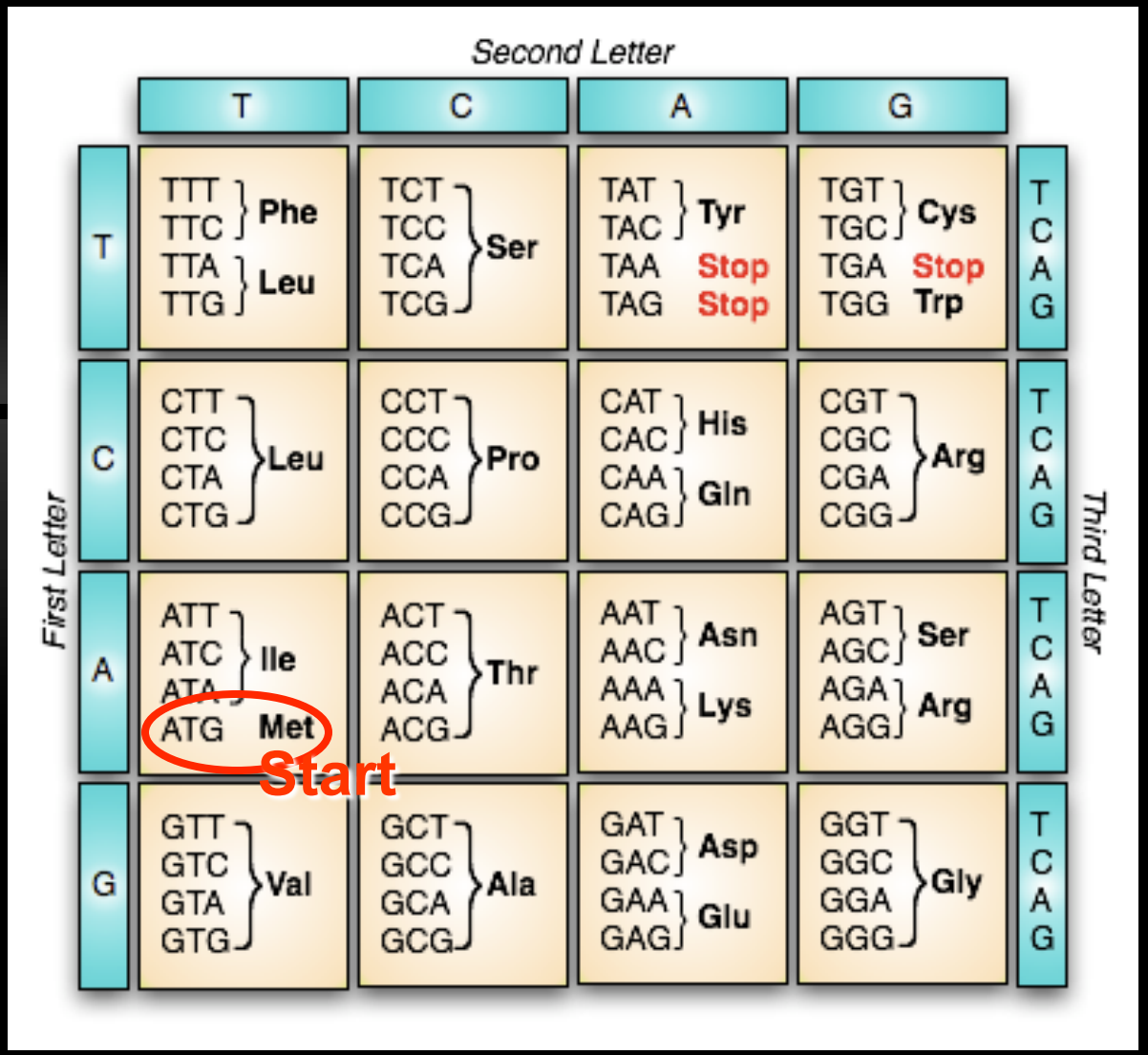
- 20 amino acids and
- start/stop codons

Genetic codes can vary among species

DNA RNA
T ≈ U

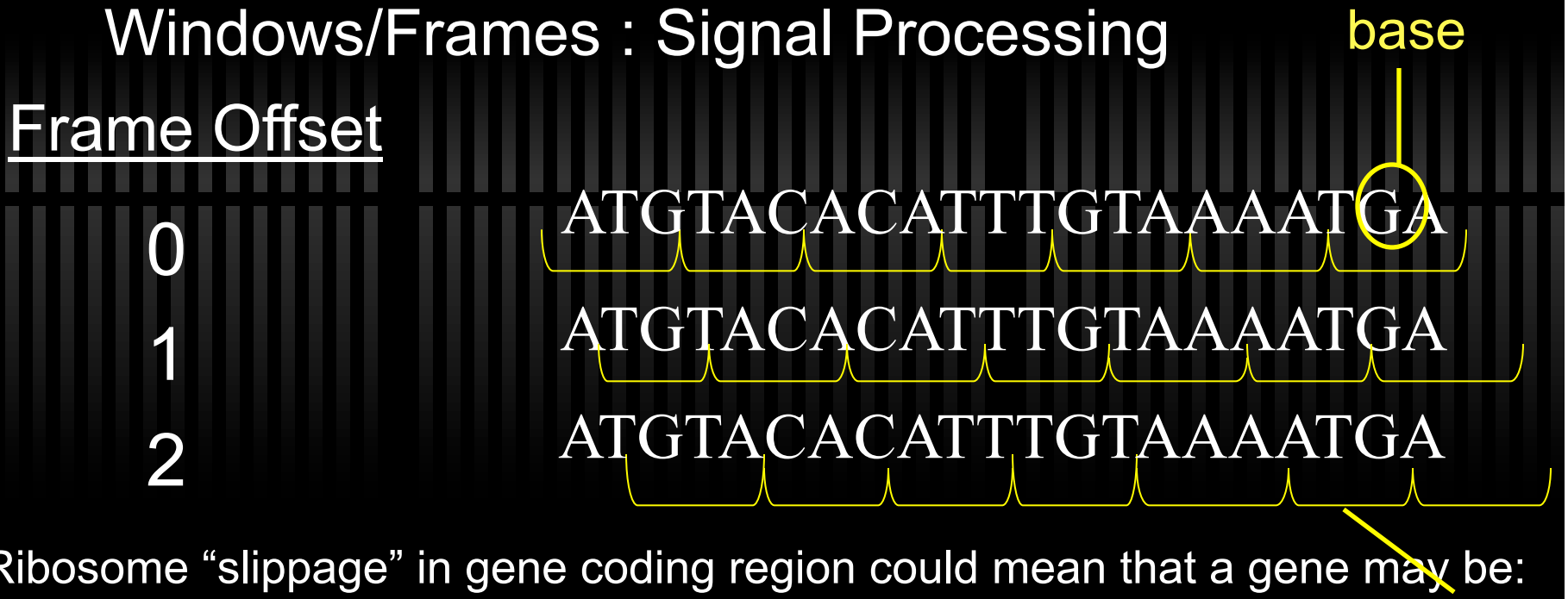


Genetic Code



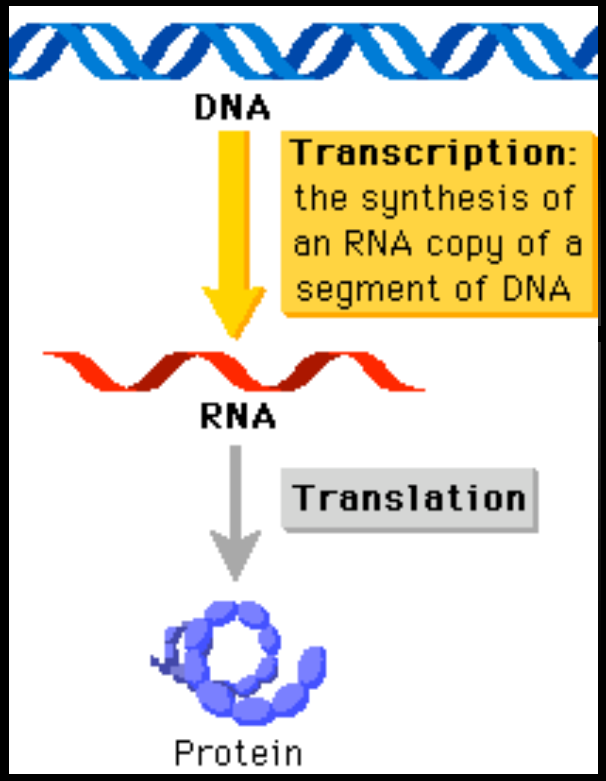
Open Reading Frames

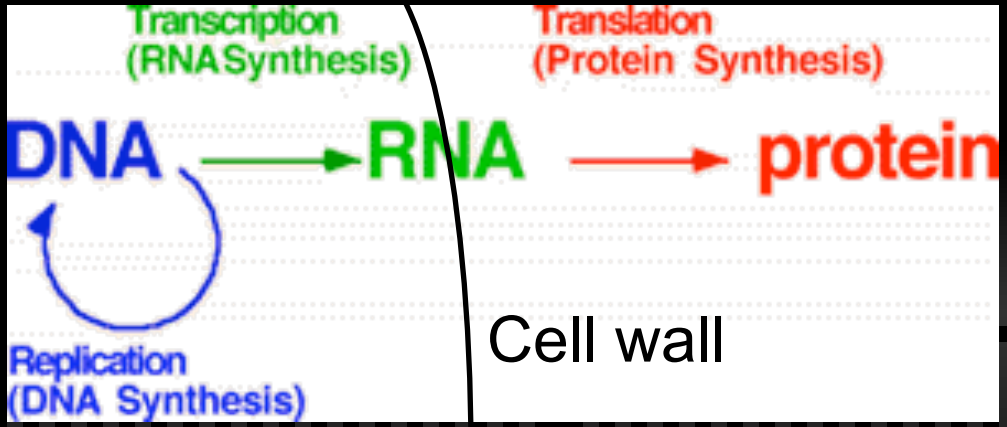
- Open Reading Frames (ORFs) : Biology
  Windows/Frames : Signal Processing



- Ribosome “slippage” in gene coding region could mean that a gene may be:
  1) Misinterpreted
  2) Not stopped
  3) Truncated early

Replication / Transcription / Translation





Prokaryotes vs. Eukaryotes

Animation: http://www.johnkyrk.com/DNAtranscription.html
http://www.johnkyrk.com/DNAtranslation.html

Structural DNA differences between Eukaryotic and Prokaryotic

- ✓ Prokaryotes – Cells without a nucleus
- ✓ Eukaryotes – Cells with a nucleus

(Eukaryotes engulfed other prokaryotes into a symbiotic relationship a long time ago)