DNA

We will discuss factors relating to the structure, properties, and uses of deoxyribonucleic acid (DNA).

- Purpose
- Structure
- Replication
- Applications
  - DNA Fingerprints
  - Genetics

Size Considerations

The following is known about human DNA.

- If stretched out, the DNA in a single cell would be ∼2 meters long.
- DNA is divided between 23 chromosomes
- Our DNA contains ∼20,000-25,000 genes
  - (Based on Human Genome Project)

DNA's Purpose

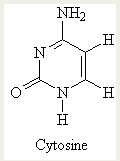
DNA contains our "genetic code" - inherited physical traits.

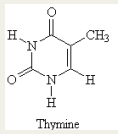
- What is known.
  Certain nucleotide sequences carry the "code" for synthesis of proteins
- What is unknown.
  98% DNA is either "junk" or (more likely) we don't what is does.

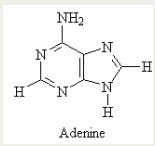
See article by Tom Bethell in The American Spectator, March 2004.

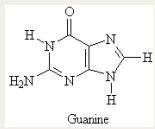
DNA Structure

DNA is composed of four types of nucleotides:



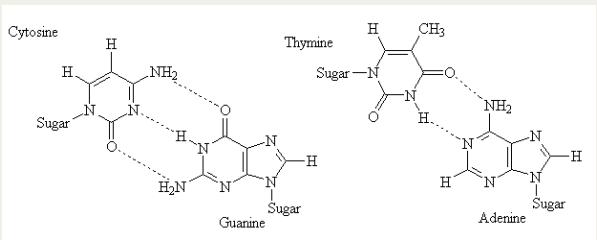






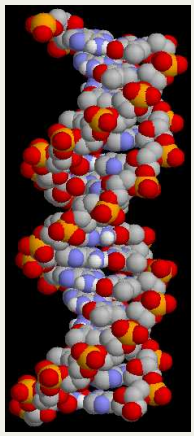
For more information, see Nucleic Acids Handout.

Base Pairs



Adenine always pairs with Thymine (A-T pair).
Cytosine always pairs with Guanine (C-G pair).

Double Helix



Replication

Since each nucleotide forms a “match” with only a single type of nucleotide, if one strand is known, the other can be determined.

–A– –C– –G– –T– –A– –A– –T– –T–

Replication

Since each nucleotide forms a “match” with only a single type of nucleotide, if one strand is known, the other can be determined.

–A– –C– –G– –T– –A– –A– –T– –T–
–T– –G– –C– –A– –T– –T– –A– –A–

Polymerase Chain Reaction

PCR is a method for synthesizing identical copies of DNA from a very small sample.
The General procedure is as follows.

- A DNA molecule is heated to separate into two strands.
- Free nucleotides (and primer) added to synthesize complementary strands.
- Repeat as needed.

DNA Doubling

—-A–C–G–T–A–T–A–G–G–C—-
—-T–G–C–A–T–A–T–C–C–G—-

DNA Doubling

—-A–C–G–T–A–T–A–G–G–C—-
—-T–G–C–A–T–A–T–C–C–G—-
⇓

—-A–C–G–T–A–T–A–G–G–C—-
+
—-T–G–C–A–T–A–T–C–C–G—-

DNA Doubling

—-A–C–G–T–A–T–A–G–G–C—-
—-T–G–C–A–T–A–T–C–C–G—-
⇓

—-A–C–G–T–A–T–A–G–G–C—-
+
—-T–G–C–A–T–A–T–C–C–G—-
⇓

—-A–C–G–T–A–T–A–G–G–C—-
—-T–G–C–A–T–A–T–C–C–G—-
+
—-A–C–G–T–A–T–A–G–G–C—-
—-T–G–C–A–T–A–T–C–C–G—-

PCR - Exponential Growth

Which would you rather have, a $1,000,000 or a penny a day, doubled every day for a month?

PCR - Exponential Growth

Which would you rather have, a $1,000,000 or a penny a day, doubled every day for a month?

$$1 \longrightarrow 2 \longrightarrow 4 \longrightarrow 16 \longrightarrow 32 \longrightarrow \ldots$$

- After 10 cycles, 1024 times as much.
- After 20 cycles, $\sim$1 million times as much.
- After 30 cycles, $\sim$1 billion times as much.

In PCR, $\sim$1-2 minutes/cycle.

DNA Fingerprinting

- Collect DNA from “crime scene”.
- Use PCR to create large quantities of identical copies of DNA.
- Cut into small pieces using Restriction Enzymes
- Separate pieces based on size using Gel Electrophoresis

DNA Fingerprinting

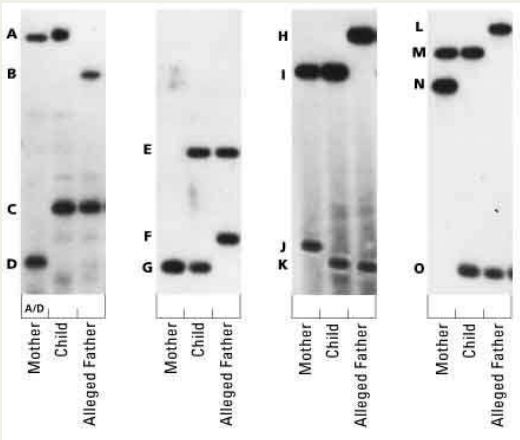
(From St. Anselm College)

Paternity Testing

“Mommy and Daddy love each other very much ...”

Children have DNA from both parents. All DNA fragments must come from either father OR mother.

Paternity Testing Example



(From PBS website)

RNA

RNA is used primarily for protein synthesis.
There are three different types of RNA.

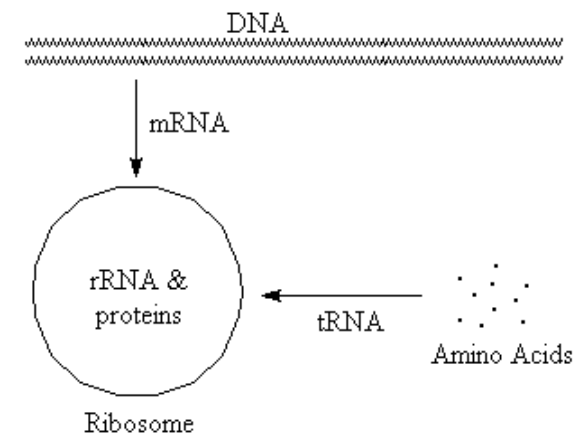
- messenger RNA (mRNA) - transcribes (copies) genetic code from DNA.
- transfer RNA (tRNA) - transports amino acids to the site of protein synthesis.
- ribosomal RNA (rRNA) - responsible (along with some protein) for translating the DNA code into an amino acid sequence for protein synthesis.

Protein Coding

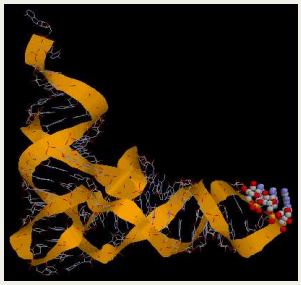
Problem:
* Only four nucleotides to code for 20 amino acids
Solution:
* Use more than one.
(Analogous to 26 letter alphabet ⟶ all possible words)

It requires a three-nucleotide sequence to code for all 20 amino acids.
(There are actually 64 ways to arrange three nucleotides)

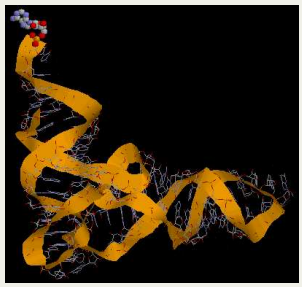
Analogy



tRNA Structure



Anti-coden



Amino acid site

Insulin Production

Insulin contains 51 amino acids.
Laboratory synthesis too difficult.
Insulin obtained from:

- Slaughterhouses (Cows or Pigs)
- Bacteria using Recombinant DNA techniques

Genetic Disease

- Relatively rare
- Error in DNA ⟶ synthesis of “bad” protein
- Usually “triggered” by something
- Examples include Down’s syndrome, ALS, ...

Chromosomes

- Humans contain 23 pairs of chromosomes.
- Children receive half of their chromosomes from each parent.
- Genetics often analyzed using **Punnett Squares**.

Genetics

Example, if both parents are **heterozygous**, they have a dominant (**R**) and recessive (**r**) gene for a particular trait:

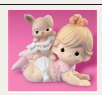
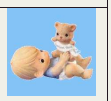
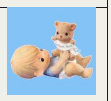
		Dad	
		R	**r**
Mom	**R**	RR	Rr
	r	Rr	rr

25% of children will have recessive trait (**rr**).

75% will show characteristic of dominant trait (**R**).

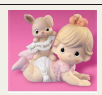
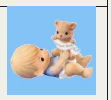
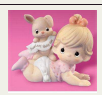
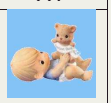
X-linked disease - Mom

Mother 'normal', but has recessive gene (x) for disease. For example, this occurs with hemophilia, which is a disease that prevents blood from clotting.

		Dad	
		X	**Y**
Mom	**X**	 XX	 XY
	x	 Xx	 xY

X-linked disease - Dad

Dad carries recessive gene (x) for disease. Because he has only one X chromosome, he also carries disease.

		Dad	
		x	**Y**
Mom	**X**	 xX	 XY
	X	 xX	 XY

Y-linked Genetics

Traits on "Y" chromosome

- Comes from father
- Passed to all sons (∼100%)
- Never given to daughters
- Almost always expressed (X $\neq$ Y)
- Diseases relatively rare

Non-Dominant Traits

For some traits, combinations of different genes gives rise not to the dominant trait but a combination (**incomplete dominance**).

- Ex. – For some flowers, R_{red} + $r_{yellow} \Rightarrow Rr_{orange}$

Some genetic traits, such as skin color, are governed by more than one type of gene (**polygenic**).

- Ex. – Skin color in humans determined by at least three different genes, whose effects are additive.

Skin Color

For simplicity, assume only two genes (A & B) determine skin color.

		Dad			
		AB	**Ab**	**aB**	**ab**
Mom	**AB**	AABB	AABb	AaBB	AaBb
	Ab	AABb	AAbb	AaBb	Aabb
	aB	AaBB	AaBb	aaBB	aaBb
	ab	AaBb	Aabb	aaBb	aabb

GM Foods - Web Resources

- New Scientist: Special Report, October 2003
  Focus primarily on European objections to GM
- Colorada State University
  University site, focusing on education.
- Scientific American, April 2001
  Range of articles dealing with this topic.
- PBS "Harvest of Fear" Web Site
  This site is based on the Nova/Frontline show, first aired April 24, 2001.
- Action Bioscience
  Well referenced (but not peer-reviewed) article written June 2001, citing potential dangers of GM foods.

Genetically Modified Foods

Genetically modified foods are already in use in this country.

"In the U.S., an estimated 60 percent of processed foods in supermarkets - from breakfast cereals to soft drinks - contain a GM ingredient, especially soy, corn or canola; some fresh vegetables are genetically altered as well." Scientific American, April 2001, p. 60

"GM ingredients, in the form of modified enzymes, are found in virtually all breads, cheeses, sodas, and beers, and farmers have been raising GM food crops such as corn, soybeans, and potatoes since the mid-1990s."
"Harvest of Fear" Web Site

Making GM Foods

The following highly-simplified procedure explains how transgenic materials can be made.

- Isolate DNA of interest (produces toxins, antibiotic resistant, ...)
- Insert into a bacterium, and allow bacteria to reproduce
- Transfer DNA from bacteria to target plant (corn, rice, ...) cells
- Remove cells that don't contain new gene
- Allow plant cells to grow to maturity

See also Colorado State Univ. site - contains a nice animation of the process.

Potential Benefits

Proponents of genetically-modified foods commonly cite the following benefits.

- Herbicide Tolerance - If plant resists herbicide, then easier to kill weeds
- Insect Resistance - Should reduce reliance on insecticides
- Improved Yields - May be possible to grow more, higher nutrition food under poorer growing conditions

Potential Risks

Opponents of genetically-modified foods commonly cite the following concerns.

- Health Hazard - Very few studies to date. Some do indicate risk.

  "A review of existing scientific literature reveals that key experiments on both the environmental risks and benefits are lacking." Wolfenbarger, L.L.; Phifer, P.R. *Science* Dec. 15, 2000, *290*, 2088.

- Superweeds/Superbugs - Weeds and bugs targets by both traditional and GM toxins adapt.
- Unnatural Combinations - What is missing or added? Is it safe? Is it beneficial?

Case Study: Salmon

Aqua Bounty Technologies, Inc. has been researching transgenic Atlantic salmon.

- Reach maturity in $\frac{1}{2}$ to $\frac{1}{4}$ the time of 'normal' salmon.
- Combines genes from Chinook salmon and ocean pout.
  - Growth hormone from Chinook salmon
  - 'Antifreeze' gene 'promotor' from ocean pout
  - Result: Fish grow all year

Salmon: Warning

PBS 'Harvest of Fear' program pointed to potential dangers. A video clip from this show is available online.

- Biggest danger: escaped fish could destroy natural population

Salmon: Rebuttal

Not surprisingly, Aqua Bounty's web site contains a rebuttal to the concerns brought forth in this program. Key points:

- Destruction of native gene pool impossible because all these GM fish sterile
- Theoretical model used by Muir and Howard invalid. (Wrong species, sterile, males used, ...)
- Any fish that escape wouldn't consume more food due to location