Recent Developments in Genetic Engineering

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Shepherds 360 Church Leaders Conference
Ethics Vol. 2
16 October 2023

Disclaimer

- **My views do not represent:**
  - My employer – Duke School of Medicine or Duke University as a whole
  - My funding agency – National Institutes of Health
  - Any of the institutions where I trained
- **I will be presenting a scientific perspective today to stimulate biblical thinking about genetics, heredity, medicine, and genetic engineering**

Outline for today's talk

- Setting the foundation
- The basics of DNA and the genome
- The Human Genome Project
- Current initiatives in genetics and medicine
- Unethical and Ethical Genetic Engineering

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Creation Day 3

Genesis 1:11-13 (ESV)

“And God said, “Let the earth sprout vegetation, plants yielding seed, and fruit trees bearing fruit in which is their seed, each according to its kind, on the earth.” And it was so. The earth brought forth vegetation, plants yielding seed according to their own kinds, and trees bearing fruit in which is their seed, each according to its kind. And God saw that it was good. And there was evening and there was morning, the third day.”

Creation Day 5

Genesis 1:20-23 (ESV)

“And God said, ‘Let the waters swarm with swarms of living creatures, and let birds fly above the earth across the expanse of the heavens.’ So God created the great sea creatures and every living creature that moves, with which the waters swarm, according to their kinds, and every winged bird according to its kind. And God saw that it was good. And God blessed them, saying, ‘Be fruitful and multiply and fill the waters in the seas, and let birds multiply on the earth.’ And there was evening and there was morning, the fifth day.”

Creation Day 6

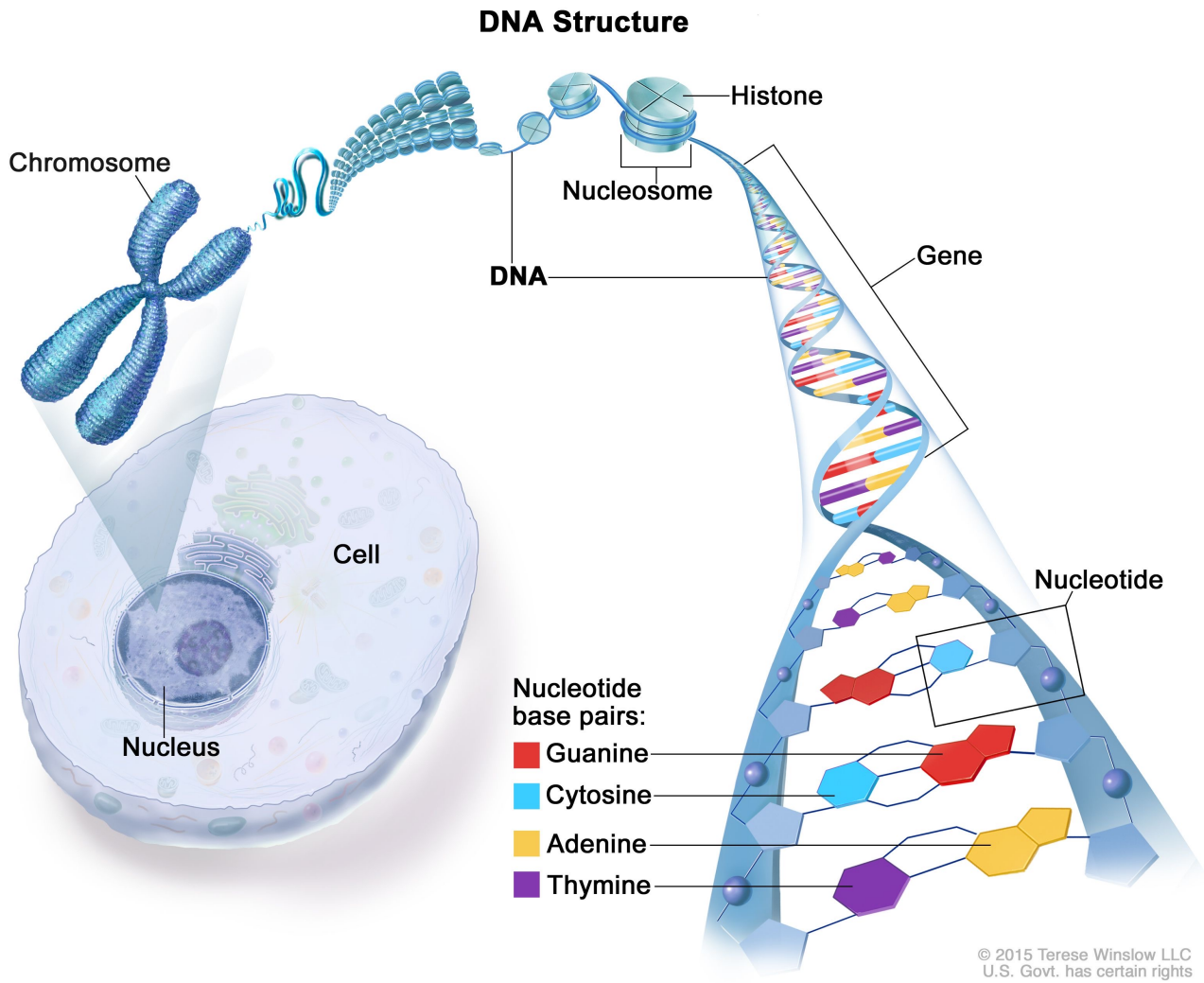
Genesis 1:24-27 (ESV)

“And God said, “Let the earth bring forth living creatures according to their kinds—livestock and creeping things and beasts of the earth according to their kinds.” And it was so. And God made the beasts of the earth according to their kinds and the livestock according to their kinds, and everything that creeps on the ground according to its kind. And God saw that it was good.

“Then God said, ‘Let us make man in our image, after our likeness. And let them have dominion over the fish of the sea and over the birds of the heavens and over the livestock and over all the earth and over every creeping thing that creeps on the earth.’ So God created man in his own image, in the image of God he created him; male and female he created them.”

The Tool God Used in Creation: DNA

- DNA is the language God used when creating life
- Instructions or code for human development and cellular function
- Required for development, growth, and health
- 4 chemical letters in the alphabet (A, C, G, T) create the DNA polymer
- Genome = complete set of DNA and code instructions
- DNA is packaged into chromosomes that we inherit



Genome: All the DNA in the Cell

The genome is the book of all our DNA. A-C-G-T are the alphabet of the genome.

Let's pretend we are reading an actual book….

…In the beginning, God created the heavens and the earth. The earth was without form and void, and darkness was over the face of the deep. And the Spirit of God was hovering over the face of the waters. And God said, "Let there be light," and there was light. And God saw that the light was good. And God separated the light from the darkness. God called the light Day, and the darkness he called Night. And there was evening and there was morning, the first day. And God said, "Let there be an expanse in the midst of the waters, and let it separate the waters from the waters." And God made the expanse and separated the waters that were under the expanse from the waters that were above the expanse. And it was so. And God called the expanse Heaven. And there was evening and there was morning, the second day. And God said, "Let the waters under the heavens be gathered together into one place, and let the dry land appear." And it was so. God called the dry land Earth, and the waters that were gathered together he called Seas. And God saw that it was good. And God said, "Let the earth sprout vegetation, plants[e] yielding seed, and fruit trees bearing fruit in which is their seed, each according to its kind, on the earth." And it was so. The earth brought forth vegetation, plants yielding seed according to their own kinds, and trees bearing fruit in which is their seed, each according to its kind. And God saw that it was good. And there was evening and there was morning, the third day. And God said, "Let there be lights in the expanse of the heavens to separate the day from the night. And let them be for signs and for seasons,[f] and for days and years, and let them be lights in the expanse of the heavens to give light upon the earth." And it was so. And God made the two great lights—the greater light to rule the day and the lesser light to rule the night—and the stars. And God set them in the expanse of the heavens to give light on the earth, to rule over the day and over the night, and to separate the light from the darkness. And God saw that it was good. And there was evening and there was morning, the fourth day….

The Genome: God's Instruction Book of Biological Life

...AGCTTCAGGCGGCTGCGACGAGCCCTCAGGCGAACCTCTCGGCTTTCC
CGCGCGGCGCCGCCTCTTGCTGCGCCTCCGCCTCCTCCTCTGCTCCGCCAC
CGGCTTCCTCCTCCTGAGCAGTCAGCCCGCGCGCCGGCCGGCTCCGTTAT
GGCGACCCGCAGCCCTGGCGTCGTGGTGAGCAGCTCGGCCTGCCGGCCC
TGGCCGGTTCAGGCCCACGCGGCAGGTGGCGGCCGGGCCCTGAGGCGC
GGGATCCGCAGTGCGGGCTCGGGCGGCCGGGCCCAGGGAACCCCGCAG
GCGGGGGCGGCCAGTTTCCCGGGTTCGGCTTTACGTCACGCGAGGGCG
GCAGGGAGGACGGAATGGCGGGGTTTGGGGTGGGTCCCTCCTCGGGG
GAGCCCTGGGAAAAGAGGACTGCGTGTGGGAAGAGAAGGTGGAAATG
GCGTTTTGGTTGACATGTGCCGCCTGCGAGCGTGCTGCGGGGAGGGGCC
GAGGGCAGATTCGGGAATGATGGCGCGGGGTGGGGGCGTGGGGGCTT
TCTCGGGAGAGGCCCTTCCCTGGAAGTTTGGGGTGCGATGGTGAGGTTC
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TGTTGTTTCTCCCACTAAAACTTTTTAAGGGCAGGAATCACCGCCGTAAC
TCTAGCACTTAGCACAGTACTTGGCTTGTAAGAGGTCCTCGATGATGGTT
TGTTGAATGAATACATTAAATAATTAACCACTTGAACCCTAAGAAAGAAG
CGATTCTATTTCATATTAGGCATTGTAATGACTTAAGGTAAAGAGCAGTGC
TATTAACGGAGTCTAACTGGGAATCCAGCTTGTTTGGGCTATTTACTAGTT
GTGTGG...

GENES = Groups of letters are words and sentences

Letters in book = DNA nucleotide

The Human Genome "Book" has 6 Billion Letters!

...AGCTTCAGGCGGCTGCGACGAGCCCTCAGGCGAACCTCTCGGCTTTCC
CGCGCGGCGCCGCCTCTTGCTGCGCCTCCGCCTCCTCCTCTGCTCCGCCAC
CGGCTTCCTCCTCCTGAGCAGTCAGCCCGCGCGCCGGCCGGCTCCGTTAT
GGCGACCCGCAGCCCTGGCGTCGTGGTGAGCAGCTCGGCCTGCCGGCCC
TGGCCGGTTCAGGCCCACGCGGCAGGTGGCGGCCGGGCCCTGAGGCGC
GGGATCCGCAGTGCGGGCTCGGGCGGCCGGGCCCAGGGAACCCCGCAG
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GAGCCCTGGGAAAAGAGGACTGCGTGTGGGAAGAGAAGGTGGAAATG
GCGTTTTGGTTGACATGTGCCGCCTGCGAGCGTGCTGCGGGGAGGGGCC
GAGGGCAGATTCGGGAATGATGGCGCGGGGTGGGGGCGTGGGGGCTT
TCTCGGGAGAGGCCCTTCCCTGGAAGTTTGGGGTGCGATGGTGAGGTTC
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GGGCGTGTGGGGACCAGGTTTTGCCTTTAGTTTTGCACACACTGTAGTTC
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GACCGATGCCCCAGGATATAGAAAATGAGAATCTGGTCCTTACCTTCAAG
AACATTCTTAACCGTAATCAGCCTCTGGTATCTTAGCTCCACCCTCACTGGT
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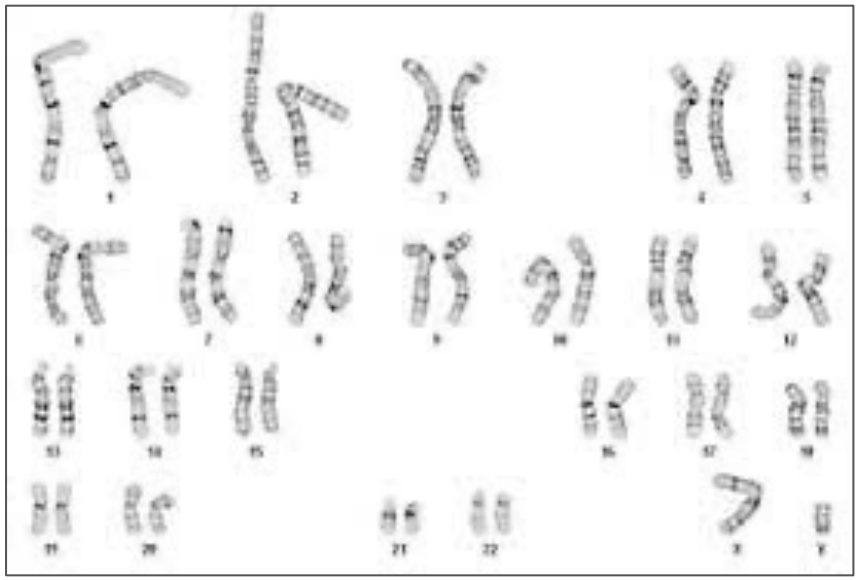
TAGCCTGCTTTATTATGATTATTTTTGTTGTTTTGGCAATGACCTGGTTACC
TGTTGTTTCTCCCACTAAAACTTTTTAAGGGCAGGAATCACCGCCGTAAC
TCTAGCACTTAGCACAGTACTTGGCTTGTAAGAGGTCCTCGATGATGGTT
TGTTGAATGAATACATTAAATAATTAACCACTTGAACCCTAAGAAAGAAG
CGATTCTATTTCATATTAGGCATTGTAATGACTTAAGGTAAAGAGCAGTGC
TATTAACGGAGTCTAACTGGGAATCCAGCTTGTTTGGGCTATTTACTAGTT
GTGTGG...

Letters in book = DNA

Groups of letters are words and sentences = GENES



DNA sentences organized into chapters = CHROMOSOMES

Human Genome Encodes for Traits and Cell Functions

...AGCTTCAGGCGGCTGCGACGAGCCCTCAGGCGAACCTCTCGGCTTTCC
CGCGCGGCGCCGCCTCTTGCTGCGCCTCCGCCTCCTCCTCTGCTCCGCCAC
CGGCTTCCTCCTCCTGAGCAGTCAGCCCGCGCGCCGGCCGGCTCCGTTAT
GGCGACCCGCAGCCCTGGCGTCGTGGTGAGCAGCTCGGCCTGCCGGCCC
TGGCCGGTTCAGGCCCACGCGGCAGGTGGCGGCCGGGCCCTGAGGCGC
GGGATCCGCAGTGCGGGCTCGGGCGGCCGGGCCCAGGGAACCCCGCAG
GCGGGGGCGGCCAGTTTCCCGGGTTCGGCTTTACGTCACGCGAGGGCG
GCAGGGAGGACGGAATGGCGGGGTTTGGGGTGGGTCCCTCCTCGGGG
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TCTCGGGAGAGGCCCTTCCCTGGAAGTTTGGGGTGCGATGGTGAGGTTC
TCGGGGCACCTCTGGAGGGGCCTCGGCACGGAAAGCGACCACCTGGGA
GGGCGTGTGGGGACCAGGTTTTGCCTTTAGTTTTGCACACACTGTAGTTC
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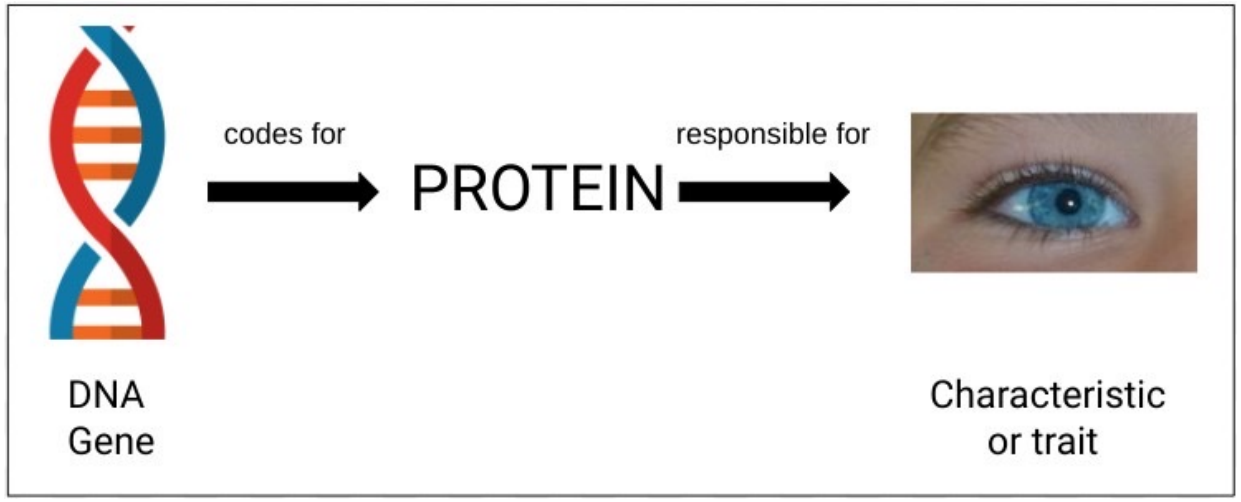
AGCGGTAACCATGCGTATTTGACACACGAAGGAACTAGGGAAAAGGCAT
TAGGTCATTTCAAGCCGAAATTCACATGTGCTAGAATCCAGATTCCATGCT
GACCGATGCCCCAGGATATAGAAAATGAGAATCTGGTCCTTACCTTCAAG
AACATTCTTAACCGTAATCAGCCTCTGGTATCTTAGCTCCACCCTCACTGGT
TTTTTCTTGTTTGTTGAACCGGCCAAGCTGCTGGCCTCCCTCCTCAACCGT
TCTGATCATGCTTGCTAAAATAGTCAAAACCCCGGCCAGTTAAATATGCTT
TAGCCTGCTTTATTATGATTATTTTTGTTGTTTTGGCAATGACCTGGTTACC
TGTTGTTTCTCCCACTAAAACTTTTTAAGGGCAGGAATCACCGCCGTAAC
TCTAGCACTTAGCACAGTACTTGGCTTGTAAGAGGTCCTCGATGATGGTT
TGTTGAATGAATACATTAAATAATTAACCACTTGAACCCTAAGAAAGAAG
CGATTCTATTTCATATTAGGCATTGTAATGACTTAAGGTAAAGAGCAGTGC
TATTAACGGAGTCTAACTGGGAATCCAGCTTGTTTGGGCTATTTACTAGTT
GTGTGG...



- The sentences are instructions used to make GENE products called PROTEINS
- PROTEINS are *ON* and *OFF* switches in our cells
- **Mutation changes the DNA (i.e. words in the book)**

The Human Genome Project

- Started in 1990 as an international effort
- Entire book of DNA (genome) of a few individuals was sequenced
- Goals were to:
  1. IDENTIFY every A-C-G-T in human cells
  2. MAP all the genes and their control elements
  3. DECIPHER the code - what do genes do?
  4. CORRELATE gene mutations to disease
  5. DIAGNOSE and PREDICT disease
  6. DEVELOP treatments for disease
  7. COMPARE genetic differences among people

- **Human genome finally complete in April 2022**

What did the Human Genome Project tell us?

- Humans have 20,000 genes
- DNA content between humans is 99.9% similar
- Each of our genomes differ by 3 million A-C-G-Ts
- The spelling of the words (gene) and the structure of our sentences (instructions for genes) in our ”genome books” make us unique biologically

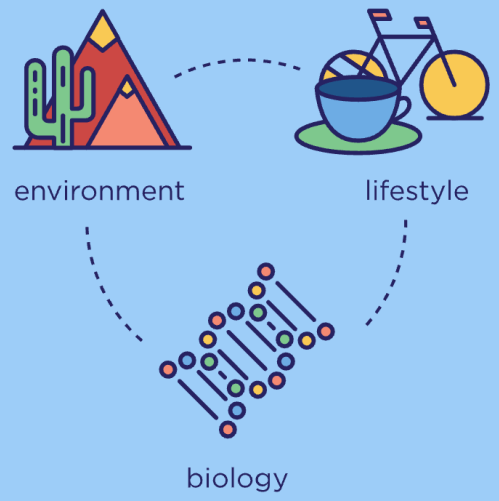
Implications of DNA Sequencing and the Human Genome Project

National Institutes of Health All of Us Program

We are building a research program of 1,000,000+ people.

The *All of Us* Research Program is an ambitious effort to gather health data from one million or more people living in the United States to accelerate research that may improve health.

OPPORTUNITIES FOR RESEARCHERS

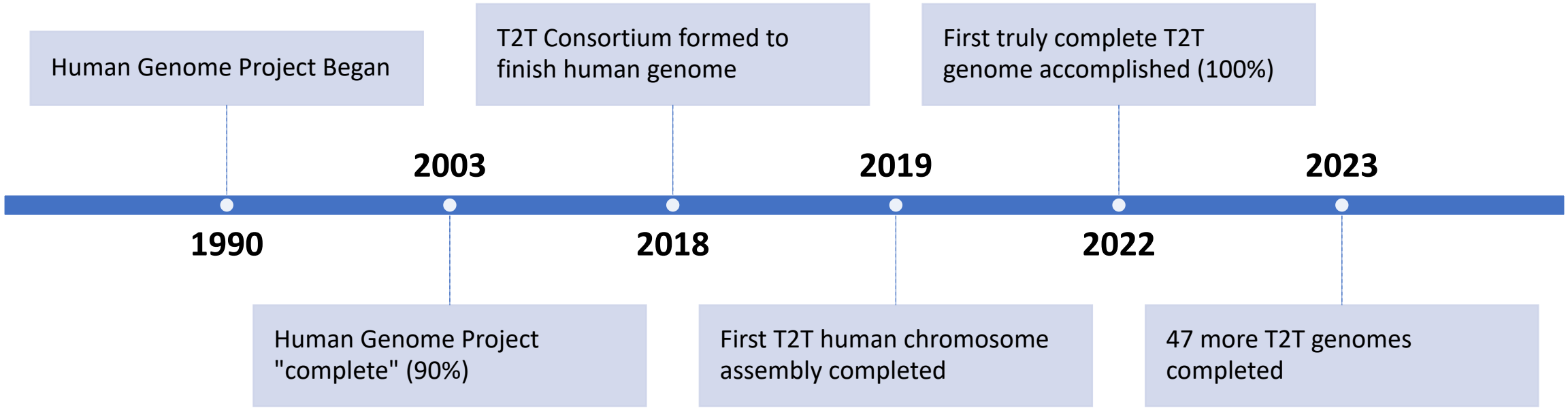


Research focuses on the intersection of three factors

As of Oct 2023: 250,000 individuals have been sequenced

https://allofus.nih.gov/

Recent Technologies have Jump-started Genomics



Current Goal in Genetics: sequence every animal & plant on earth

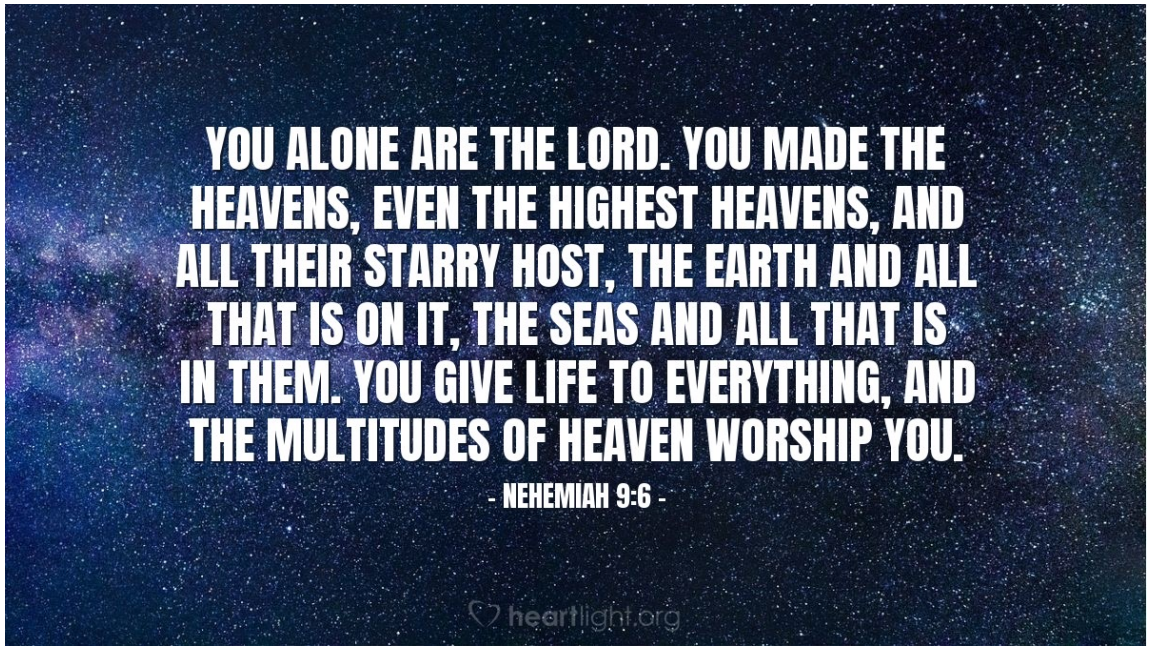
- A *moonshot* for biology, aims to sequence, catalog and characterize the genomes of all of Earth's eukaryotic biodiversity over a period of ten years.
- **Sequence 2 million animal and plant species by 2028**
- Identify additional 8-15 million new species
- Benefit human welfare
- Protect biodiversity
- Understand ecosystems

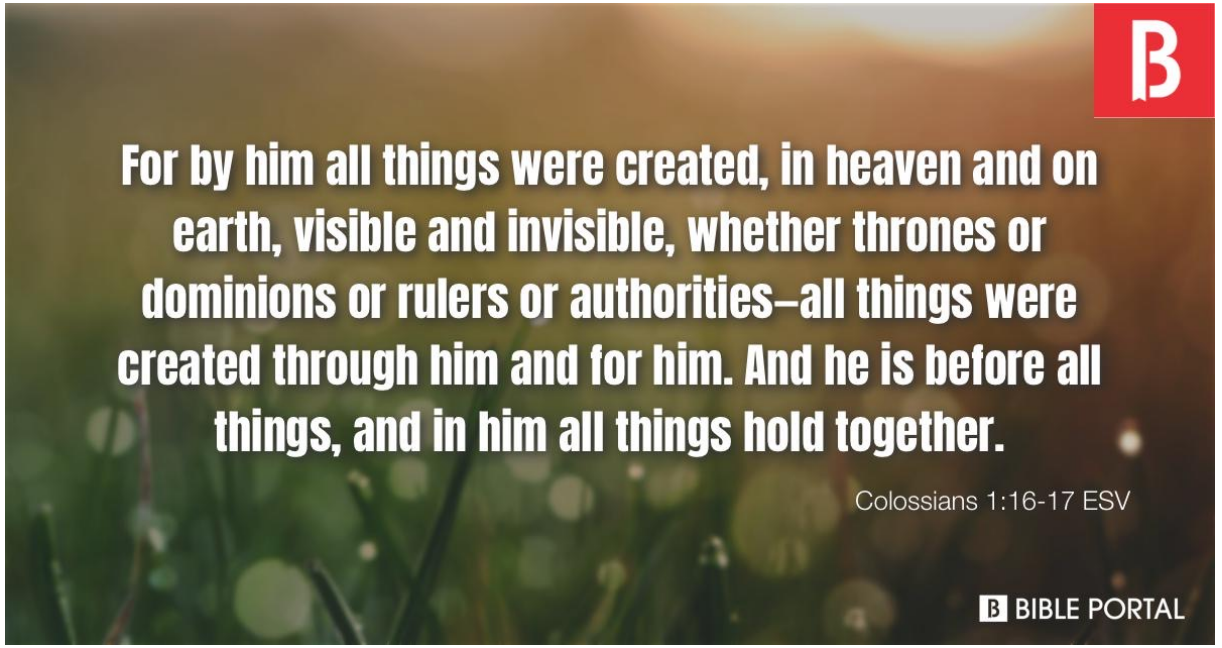
Secular View of Genetic: *Worshipping the Creation*

What is life?
Why are we here?

Christian View of Genetics: *Worshipping the Creator*

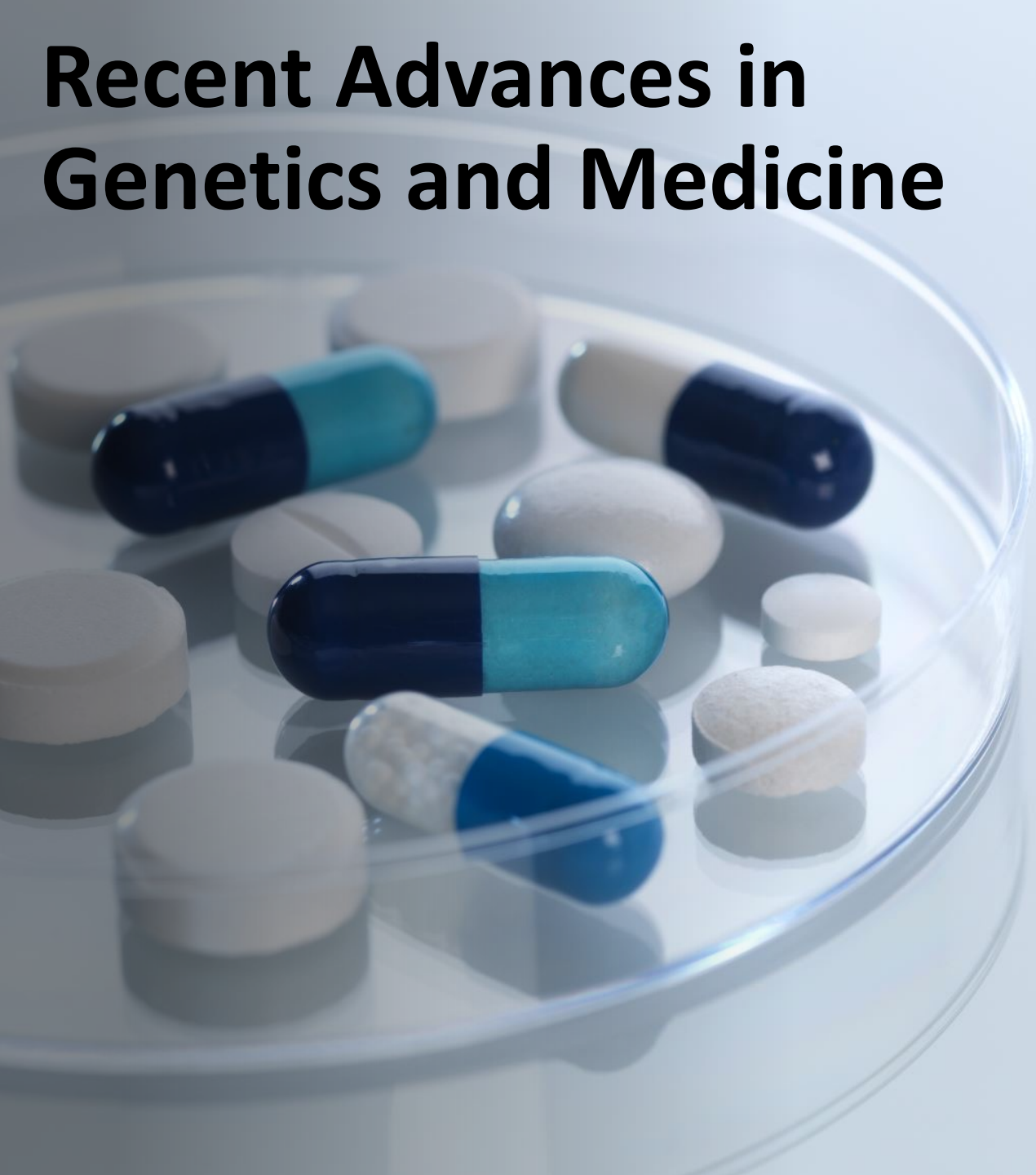
What is life?
Why are we here?

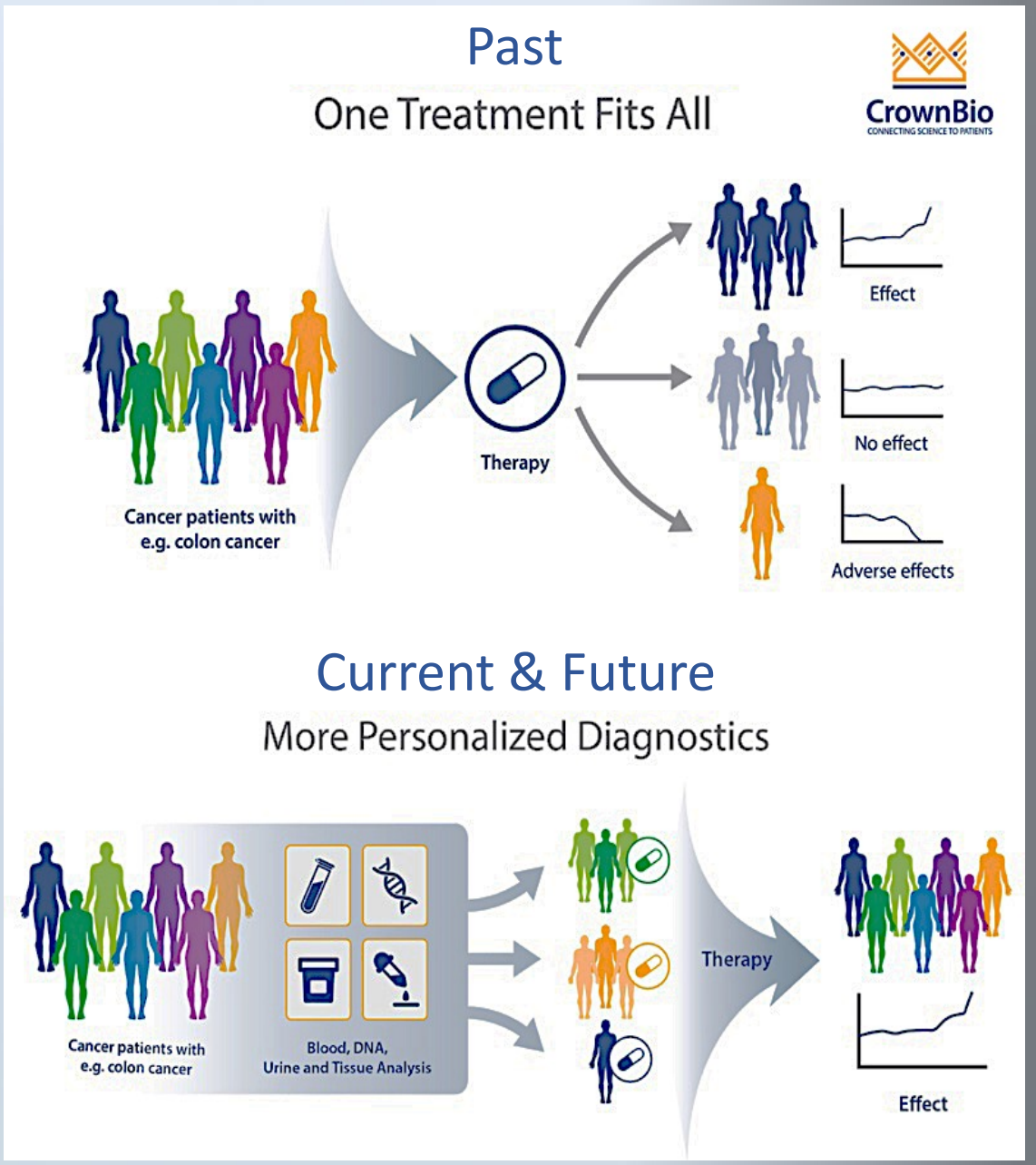




- Studying the genome is not inherently unbiblical
- What we do with genetic information matters
- Reducing suffering
- Treating disease
- Looking toward perfection in eternity

Recent Advances in Genetics and Medicine





A New Era of Personalized Genetic Medicine

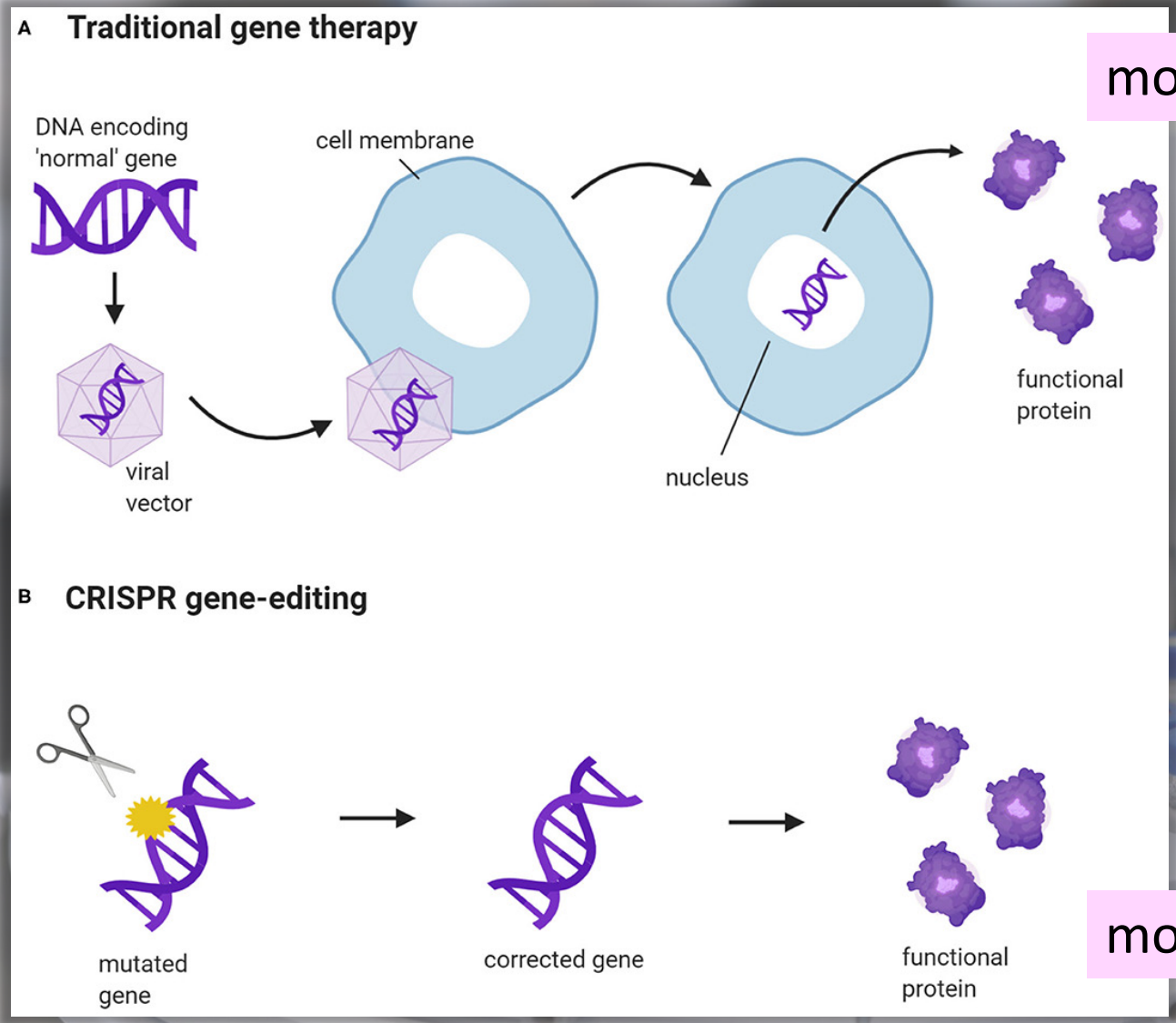
- An individual's DNA variation affects response to treatment
- A person's genome predicts response to therapy or can help develop more effective treatments
- Many hospitals/medical centers are offering to DNA sequence each consented patient
- Example: OneDukeGen - goal to sequence 100,000 individuals to "unravel the intricate connections between genetics, health, and disease."

ETHICAL IMPLICATIONS

- Why and how would I want my DNA to be used?
- Will my DNA be used for genetic engineering now or for the future?

Learn more about OneDukeGen:

CRISPR: Precise Genetic Engineering for Gene Therapy



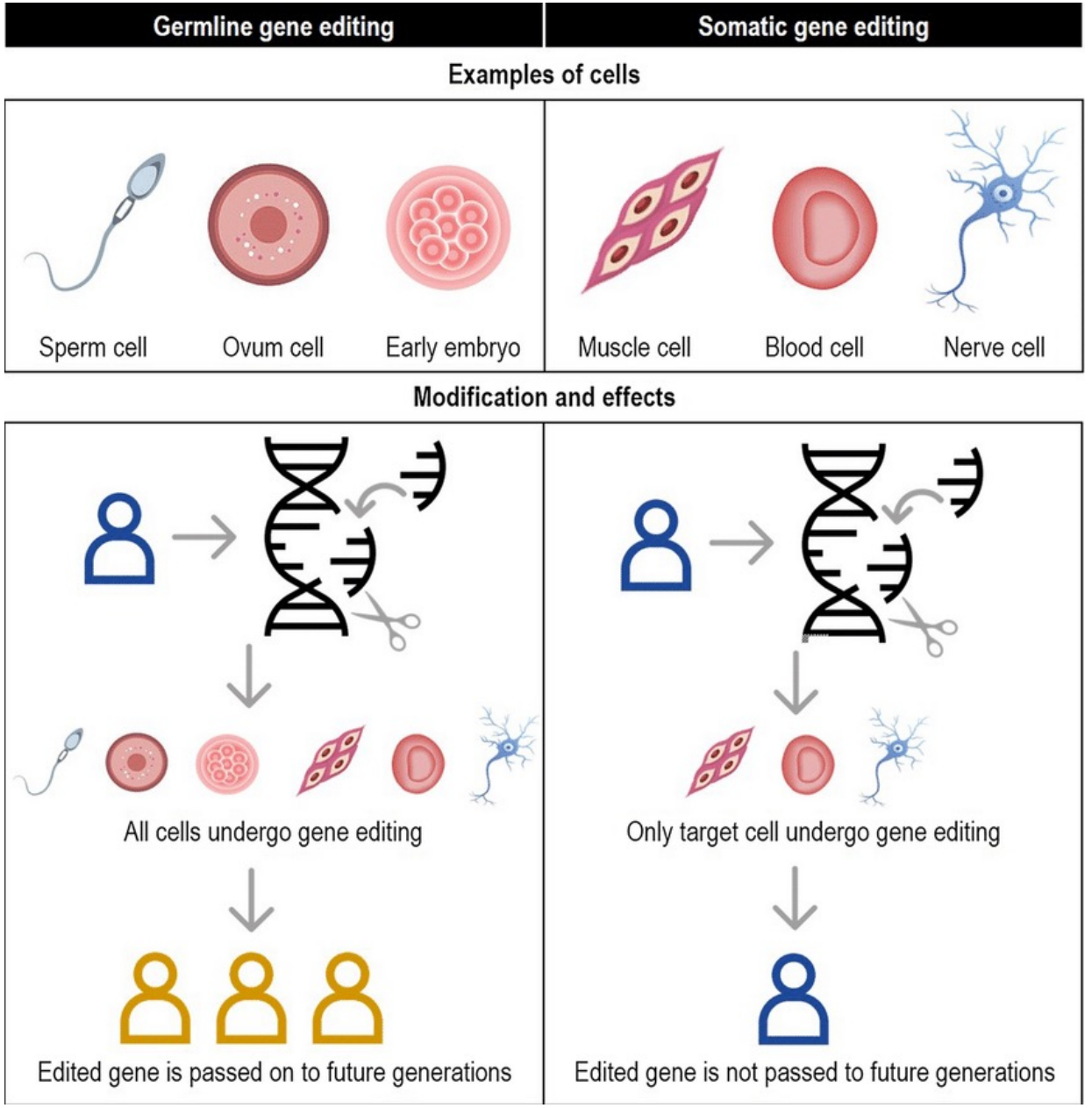
modify DNA outside cell, return it to cell

modify DNA inside cell

Where and How Genetic Engineering Occurs Matters

DNA changed in all cells

DNA changed in some cells



Graphic from Vasodavan and Das J. Health and Religion August 2022

genetic engineering of germ cells:

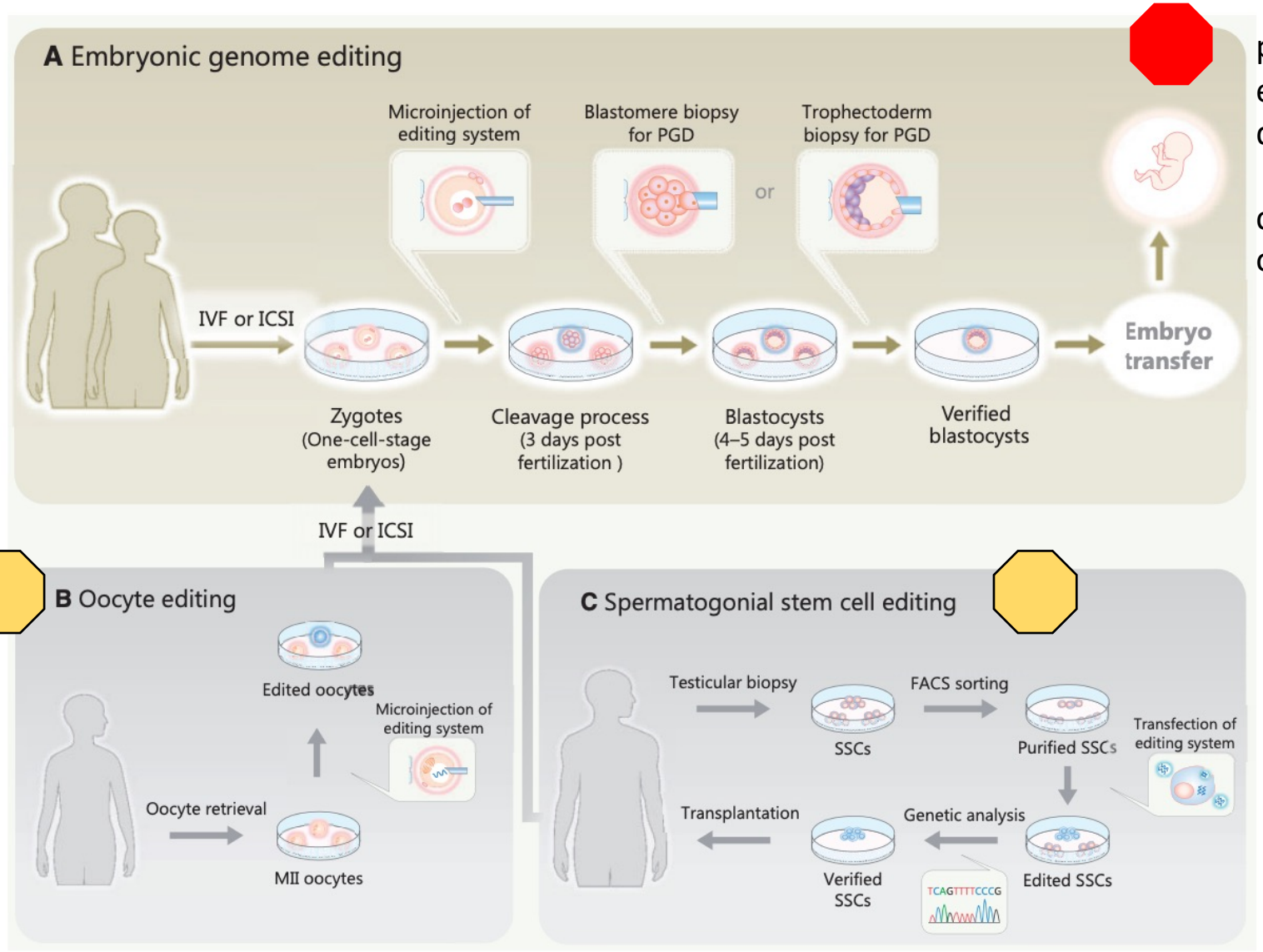
- *modifies entire genome and changes the individual from what God ordained*
- *how germ cell editing is done matters*

somatic cell genome engineering:

- *used for treatment*
- *can minimize suffering*
- *does not change the entire genome of individual*

Ethical and Biblical Issues of Genetic Engineering

Assisted Reproduction Technologies



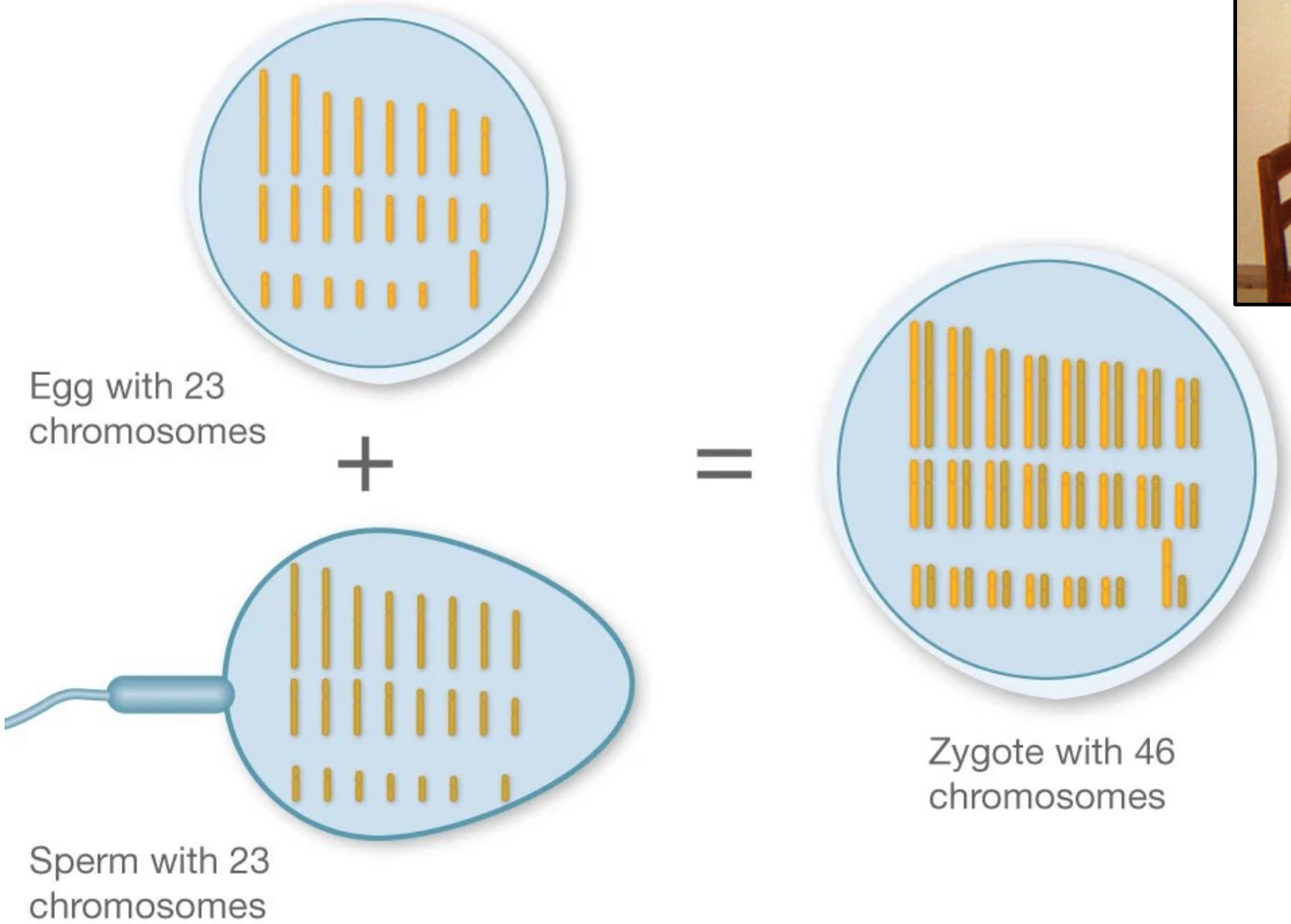
Ethical issues:

potential for embryo destruction

cryopreservation of embryos

Genomic Imprinting Supports God's Model of Procreation

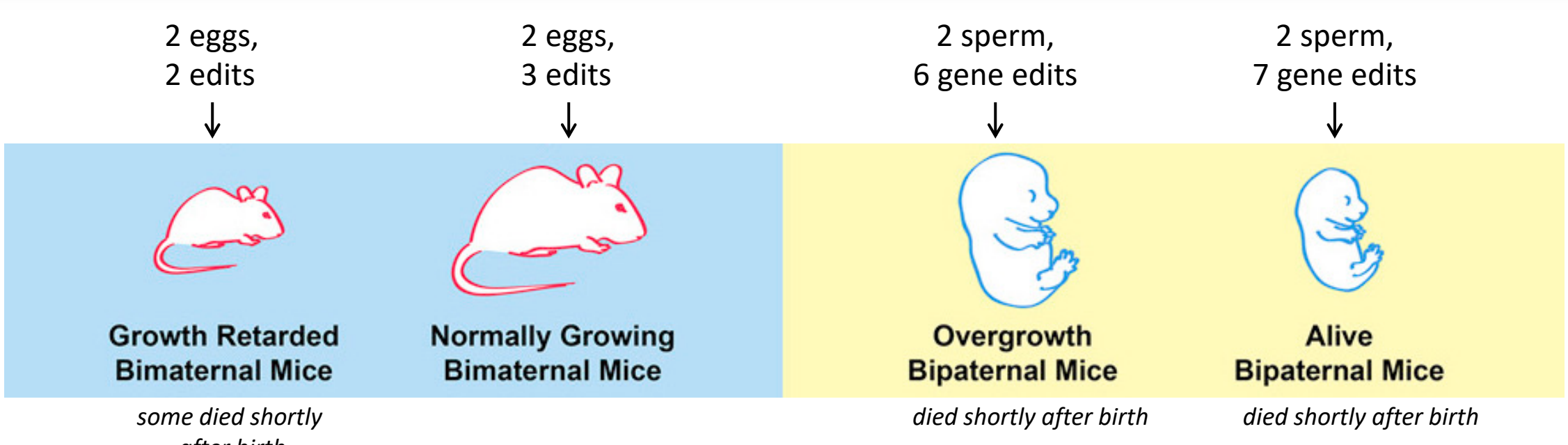
Mothers provide specific genetic information
Some genes are ON, other are OFF



Fathers provide specific genetic information
OFF genes in Mother are ON in father and vice versa

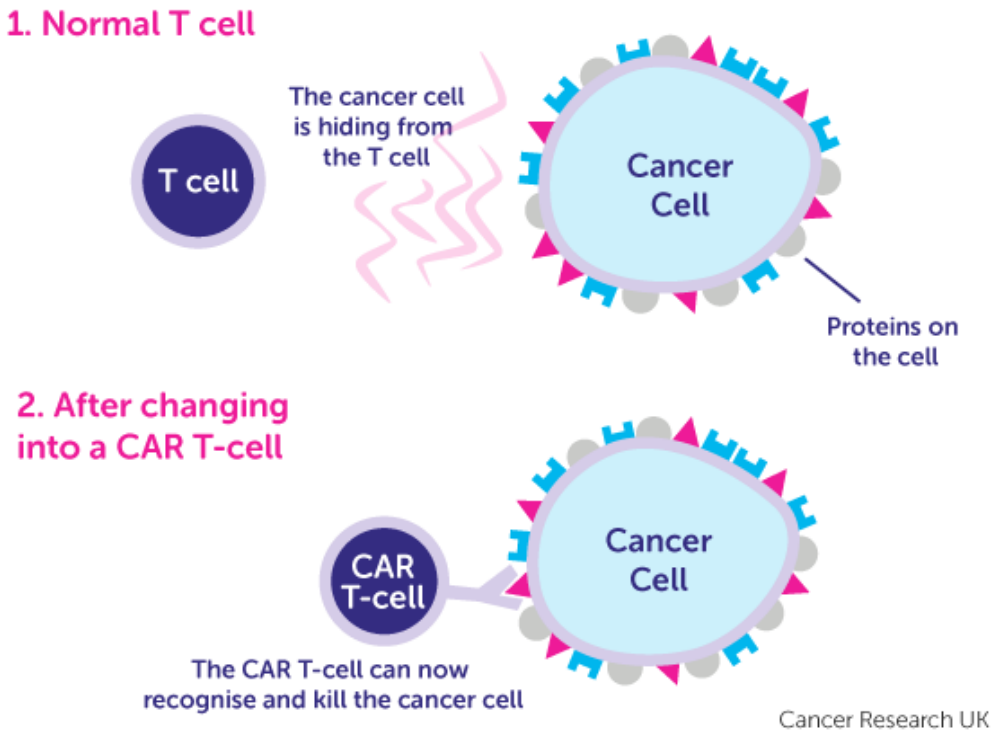
CRISPR Genetic Engineering to Create Offspring from Same-Sex Parents

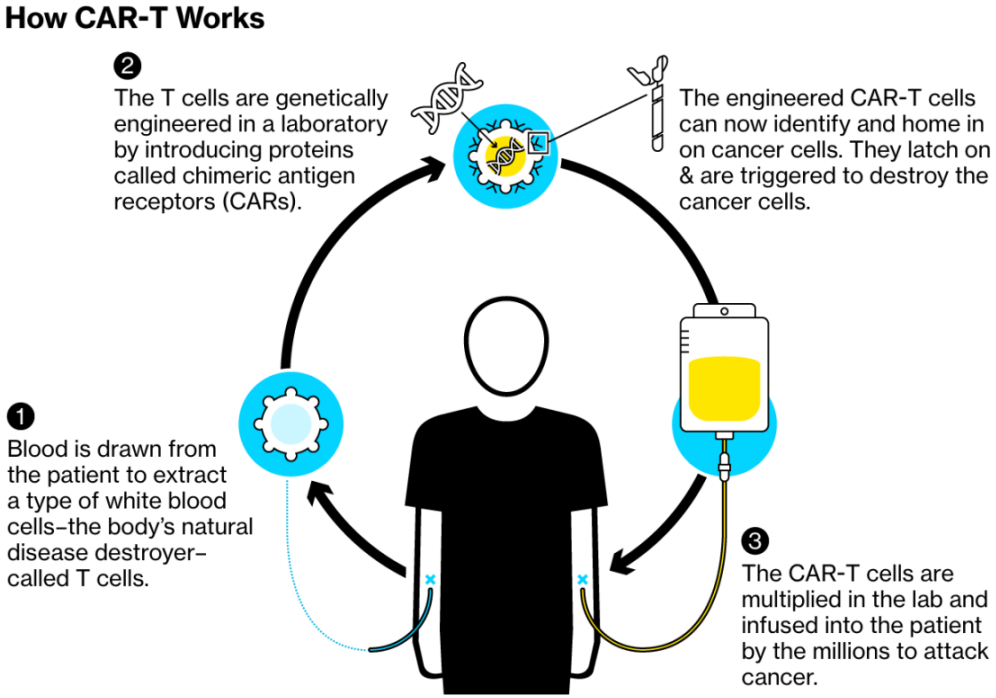
- Scientists used CRISPR to generate offspring from male-male or female-female gametes
- **Goal:** to explore reproductive options for same-sex human couples
- Needed multiple gene edits to circumvent GENOMIC IMPRINTING
  - 3 modifications in female-female embryos
  - 7 modifications in male-male embryos
- **Result:** Live offspring had many growth, developmental, and physical defects



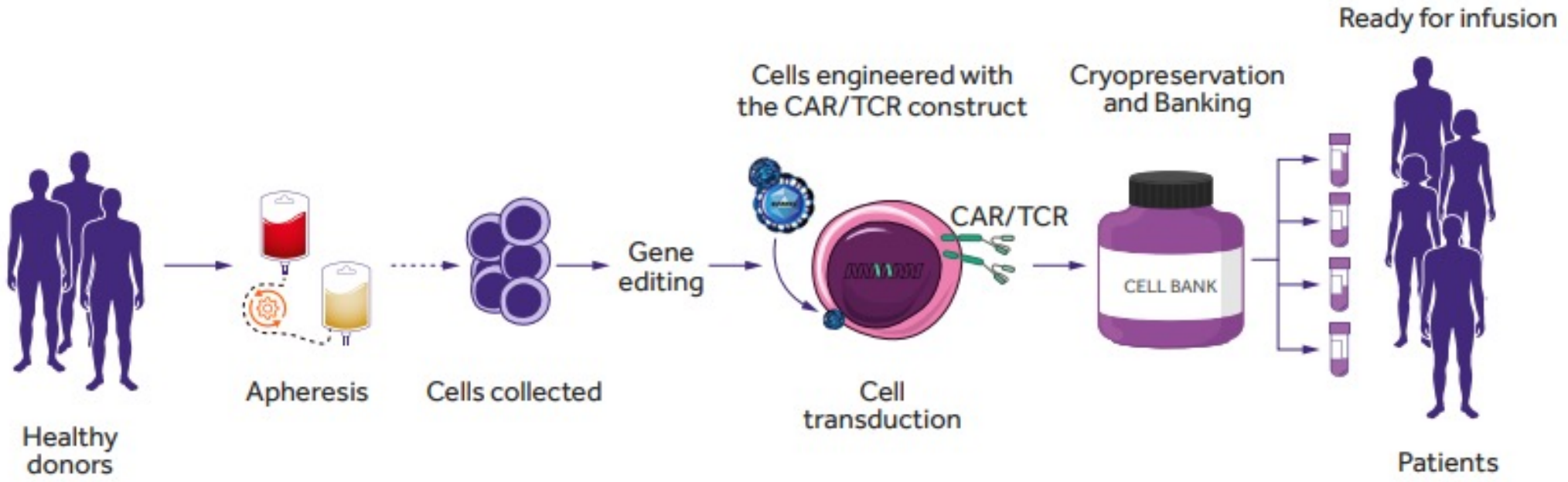
This is an unbiblical use of genetic engineering that defies God's model for marriage and procreation

Ethical Genetic Engineering: Using CRISPR to treat cancer via personalized CAR-T cell therapy



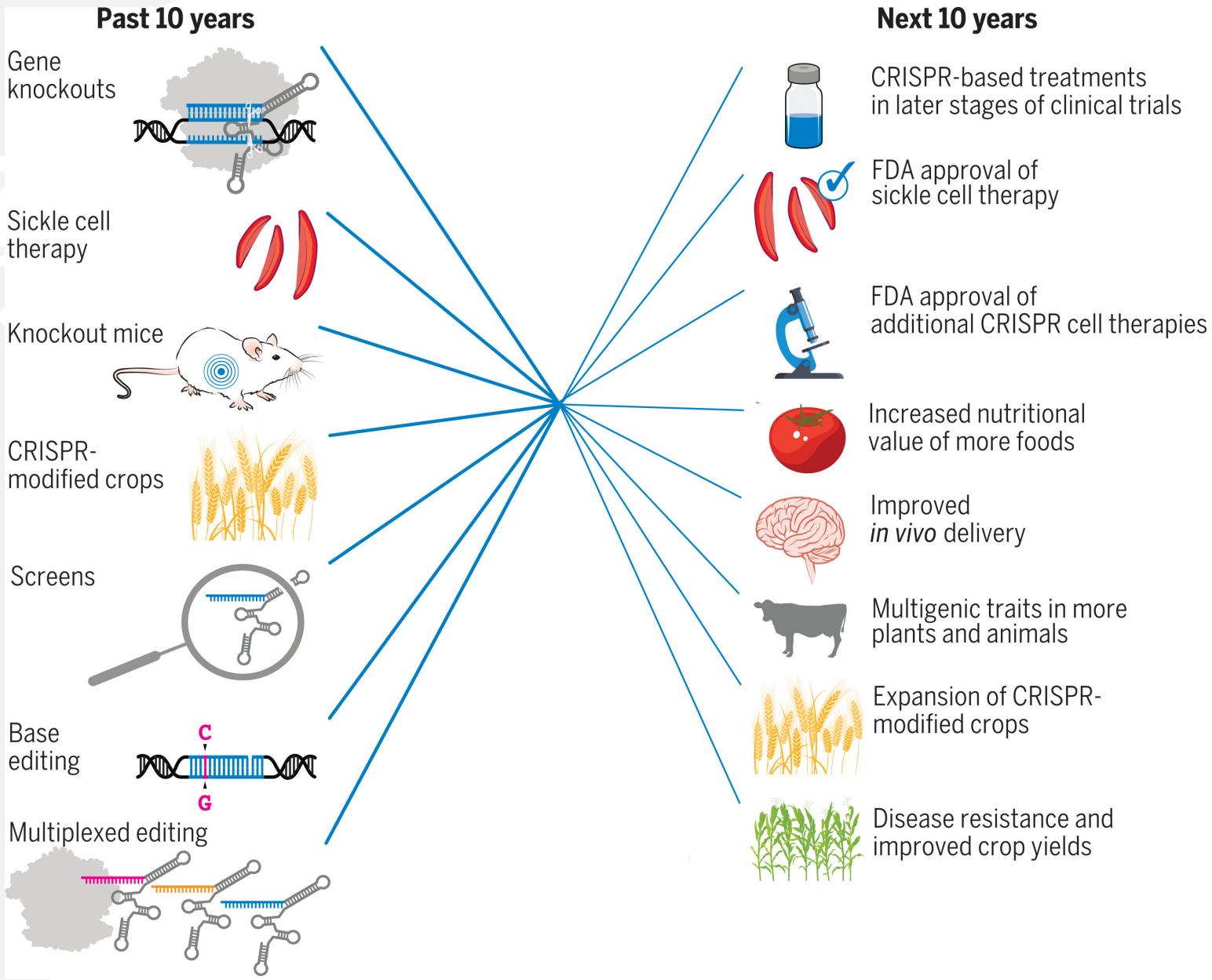


Ethical Genetic Engineering: Using CRISPR to treat cancer via expanded CAR-T cell therapy



- accelerates time to treatment
- scales to benefit greater number of patients
- able to treat leukemias, myelomas, solid tumors

Outlook for CRISPR Genetic Engineering



CRISPR technology: A decade of genome editing is only the beginning, Volume: 379, Issue: 6629, DOI: (10.1126/science.add8643)

Biblical, Moral, and Ethical Considerations in Genetic Engineering

Reason for Genetic Engineering	Is it Ethical?	Comments
Therapeutic purposes	perhaps	Will genetic engineering minimize suffering?
Enhancement purposes	no	“For the LORD does not see as man sees; for man looks at the outward appearance, but the LORD looks at the heart.” 1 Sam 16:7
Disease with no cure or treatment	perhaps	Somatic cells allow targeted therapy? Will genetic engineering minimize suffering?
In utero gene editing	perhaps	Will genetic engineering minimize suffering? Will it change genome in all cells?
Germline (sperm, egg, embryo) gene editing	perhaps	Will it change genome in all cells? Will the technology destroy embryos?

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Send question or comments to:
bsullivan36@gmail.com