

# Introduction to Genomics

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<https://ekviky.github.io/genomics-intro/>

# Genomics and Bioinformatics

## Biol 335

### Course Overview

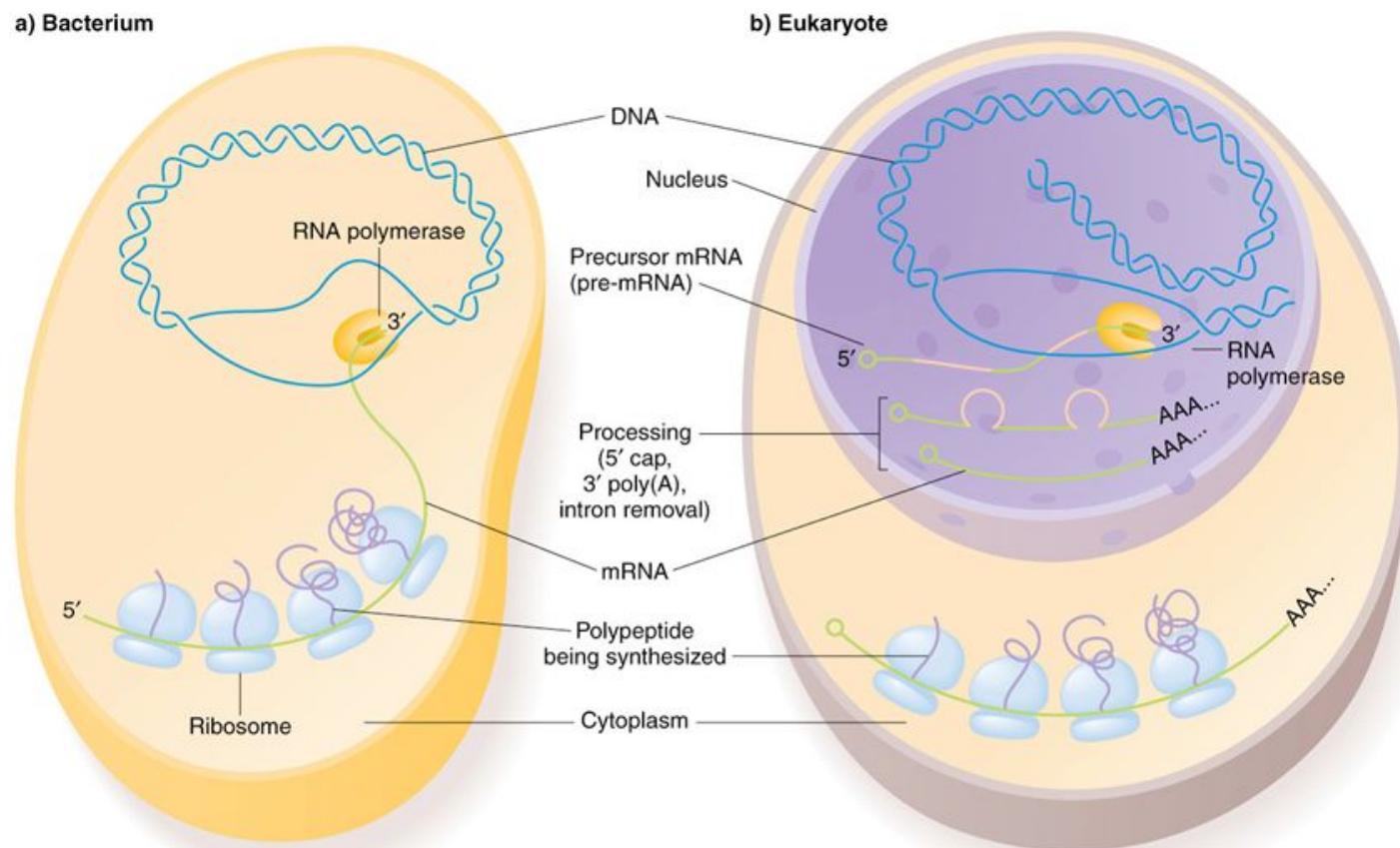
1. Overview genomes & sequencing
2. DNA sequencing & technology
3. Mutagenesis
4. Transcriptomics
5. Proteomics
6. Bioinformatics

# Genomics vs Genetics

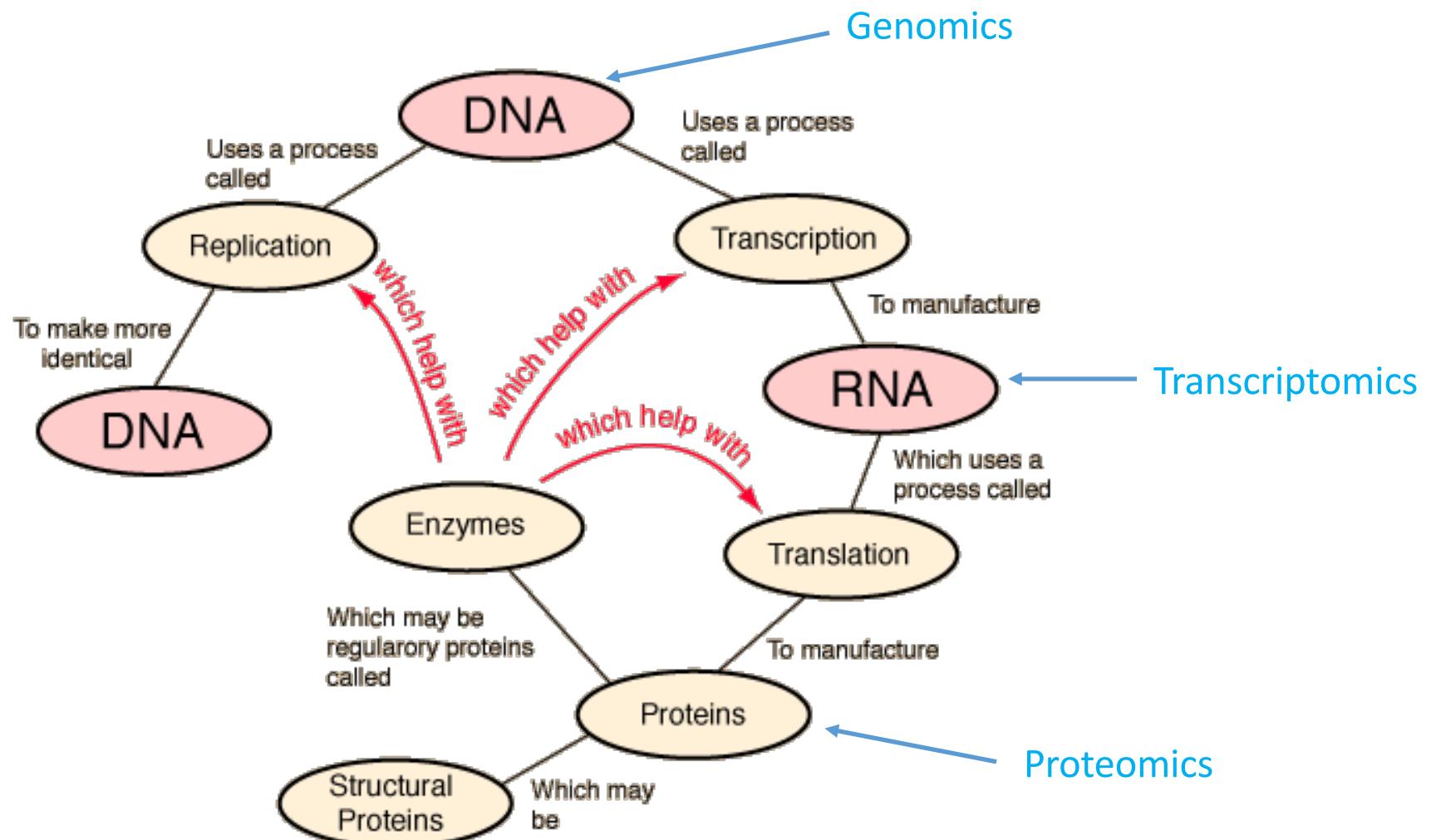
- What do they both mean?
- Genomics: The study of all DNA in a cell (a genome) and relationships between genes.
- Genetics : The study of a specific gene in a cell.

# Why are genetics and genomics important?

## Central Dogma of Biology



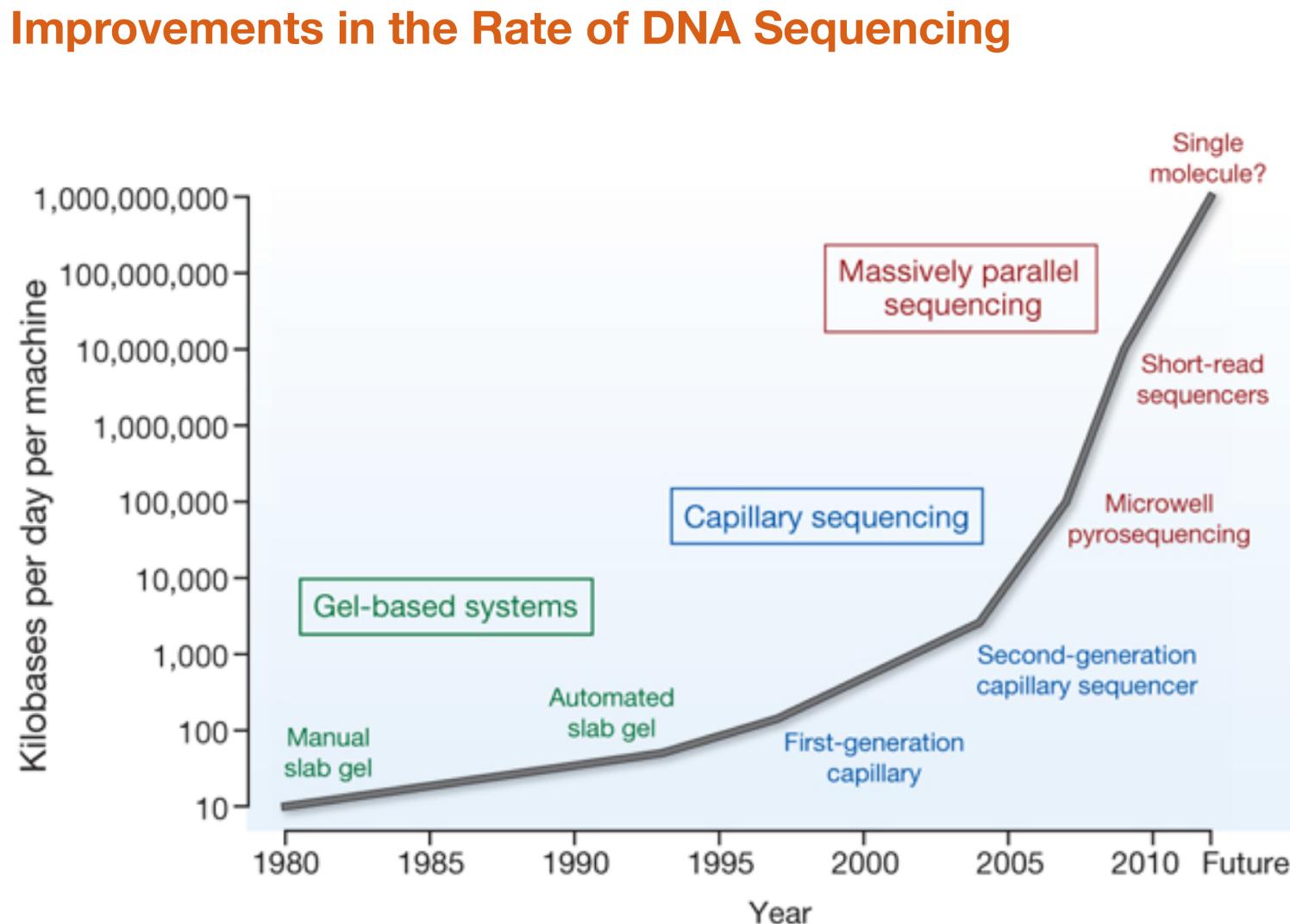
# Central Dogma of Biology



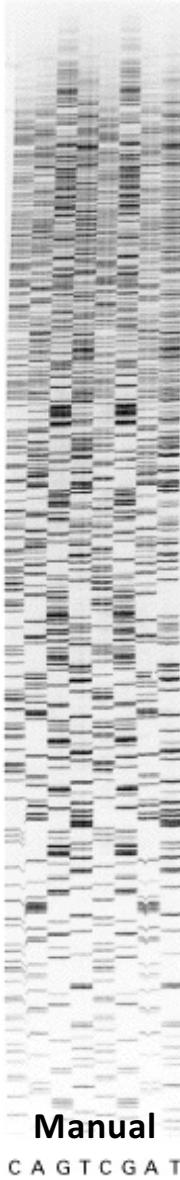
# Sequencing the Human Genome

- The first human genome draft was completed in 2001.
- It cost \$2.7bil over 13 years
- International effort:
  - universities and research groups across the United States, the United Kingdom, France, Germany, Japan and China participated.
- Now, one person can achieve this in less than 1 month for ~USD\$1,000.

# Timeline genome sequencing



# How is it achieved?



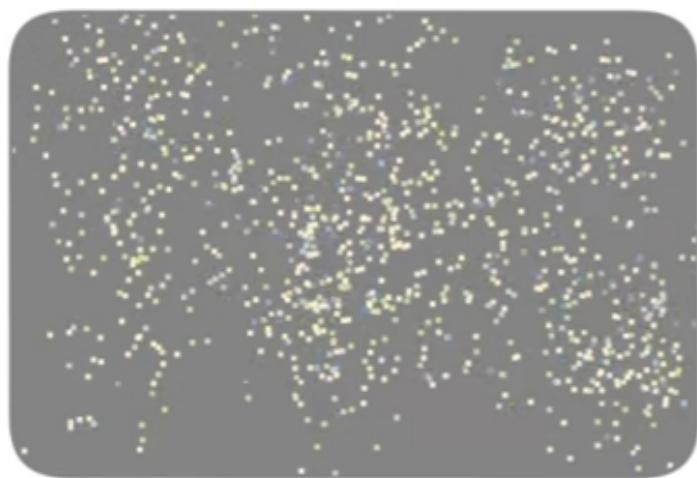
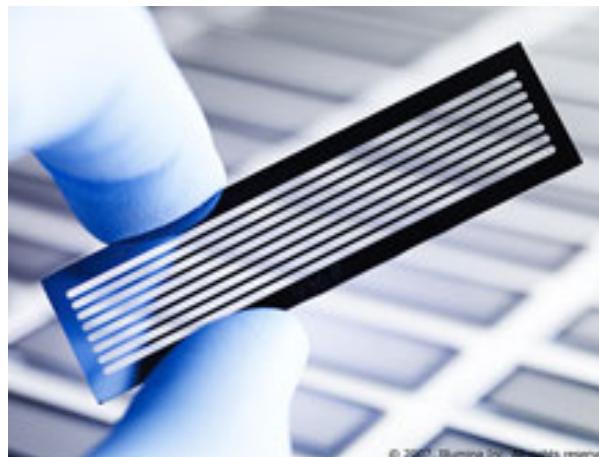
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# Next generation sequencing (NGS)



# Illumina Sequencing



Flow cell

AA TGGCTAAGGCTTACGCC  
AAAAC GCCGTACTACCTCAI  
TCTT GCAGTAGTAAGAAAC  
ACAAA TGGCTAAGGCTTAC  
ACTACCTCAGCAGTAGTAAI  
AAA GGCTAAGGCTTACGCC  
CTTACGCCGTACTACCTCAI  
TCTAGCAGTAGTAAGAAAC  
ATCAAATGGCTAAGGCTTAC  
CTTACCTCAGCAGTAGTAAI  
AAAGC CTAAGGCTTACGCC

# What next?

Now we have...

Billions of small chunks of DNA sequenced  
in a computer file...

But what does it mean?

Bioinformatics comes next!

# The full tale

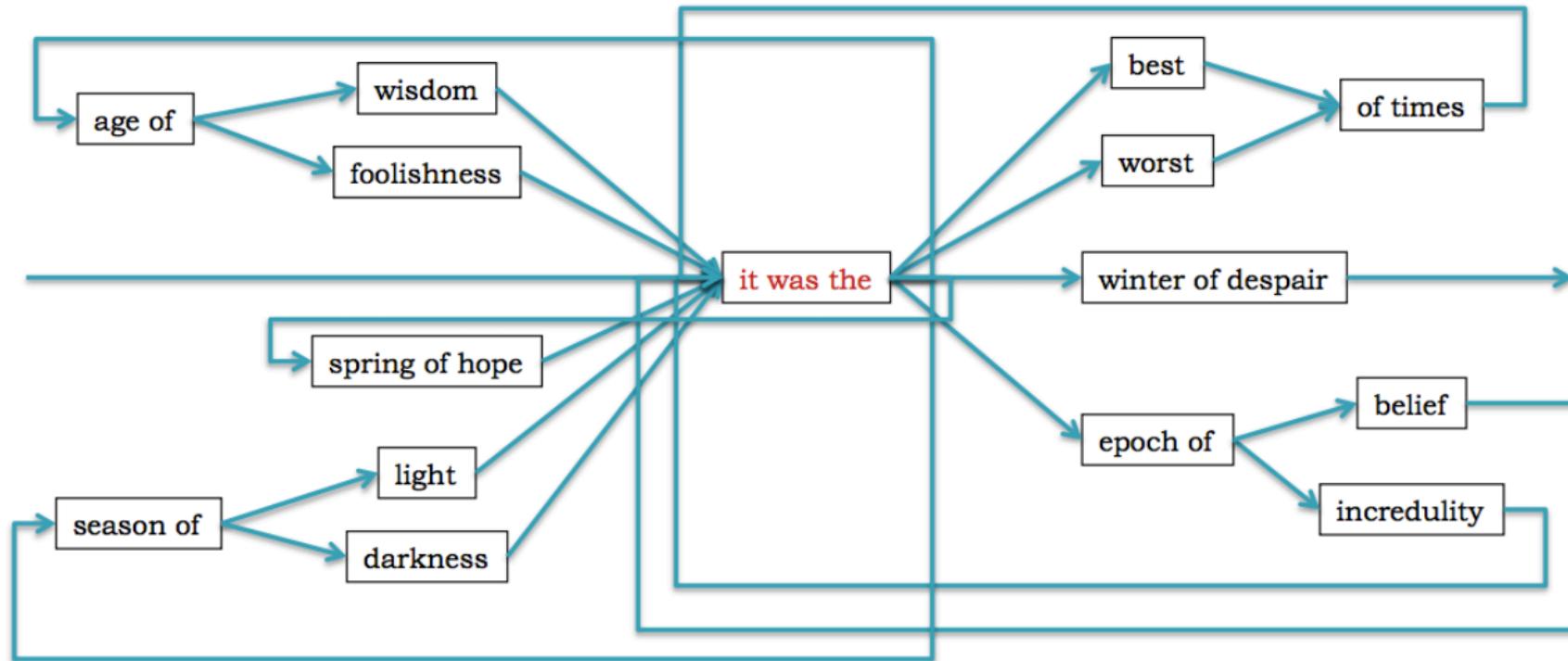
... it was the best of times it was the worst of times ...

... it was the age of wisdom it was the age of foolishness ...

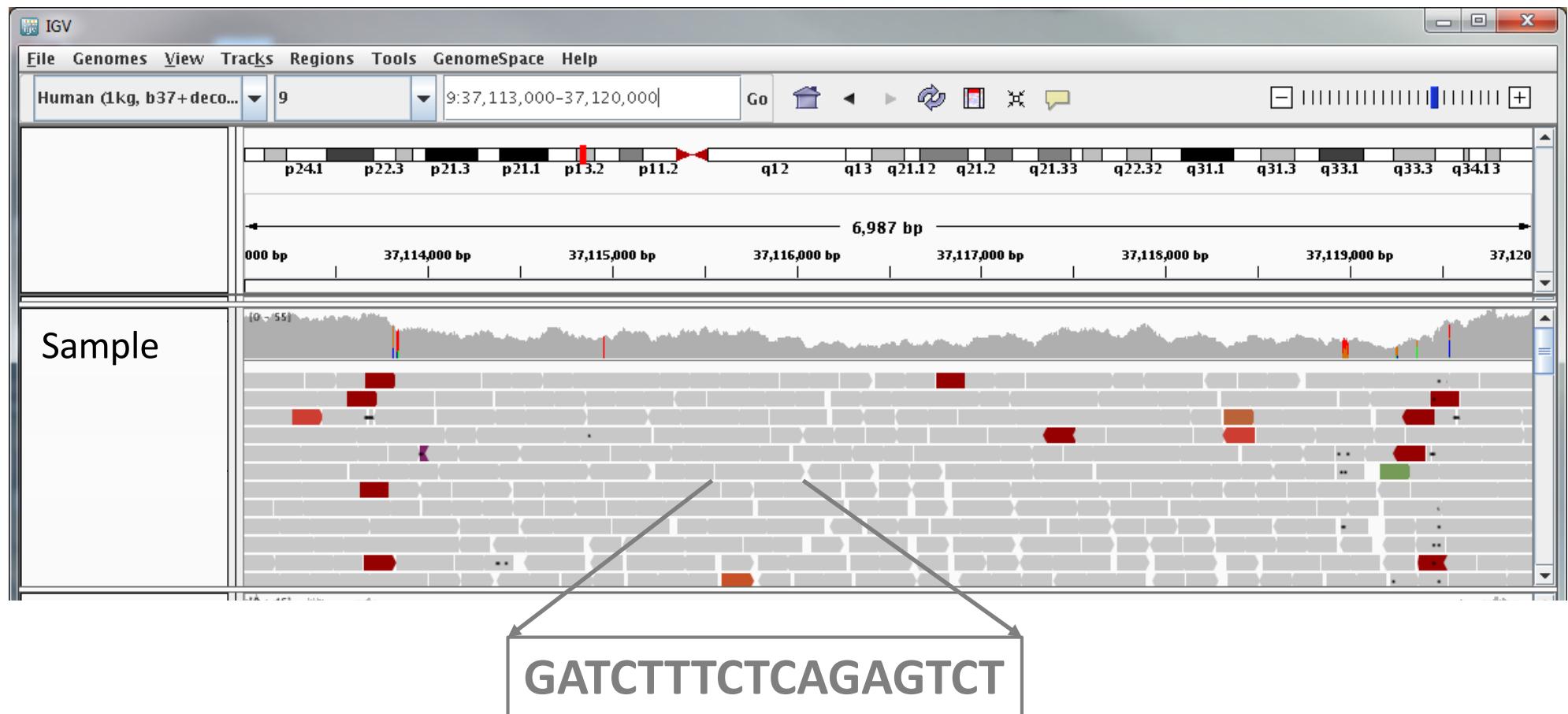
... it was the epoch of belief it was the epoch of incredulity ...

... it was the season of light it was the season of darkness ...

... it was the spring of hope it was the winter of despair ...



# Integrated Genome Viewer (IGV)



# How does genomics impact our lives?

## (Precision) Medicine

Flu transmission  
HCV and HIV treatment  
Ebola – quarantine and treatment  
Cancer – diagnosis and targeted treatment  
Diabetes – nature vs nurture  
Fertility: Diagnosis Improved IVF Processes

Zika virus  
Heritable diseases:  
Alzheimers  
Parkinsons

## Forensics

Identify suspects and victims  
Old and new evidence  
Good and bad quality samples (old DNA)

## Crops and Farming

Adaptability and resilience (weather, pesticides, fungicides)

Improved product quality e.g. cotton, Golden rice

Disease resistance genes e.g. Ash dieback

## Space Travel

Impact on DNA from being in space

## Animals

Heritable diseases:  
Muscular Dystrophy  
Degenerative Myelopathy

Heritable traits:  
coat colour

Models for human disease

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# Personalized medicine case study: prostate cancer

## Request for urgent sequencing for prostate cancer patient

- Resistant to current treatment
- WGS identified
  - Mutations in TP53, CDKN2A & RB
  - Homozygous loss of BRCA2
  - Loss of PTEN
- Patient eligible for PARP inhibitor as part of clinical trial
- 3 week turnaround from sample to results

## Oxford Mail



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### Gene study offers new hope to cancer patients



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## Health

# First 'three person baby' born using new method

By Michelle Roberts

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## 'Three-parent baby' born ahead in historic

inheriting deadly genetic diseases

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## Reproduction

# First UK baby with DNA from three people could be born next year

Clinics set to apply to offer treatment to help women with mitochondrial mutations after regulator gives green light



This article is 3 months old

1,546

Ian Sample Science editor

@iansample

Thursday 15 December 2016 11.55 GMT



The Human Fertilisation and Embryology Authority has said clinics can seek licences for the procedure.  
Photograph: Christopher Furlong/Getty Images

## Most popular



Middlesbrough 1-3  
Manchester United:  
Premier League - as it  
happened



Don't tell me you weren't  
warned about Corbyn |  
Nick Cohen



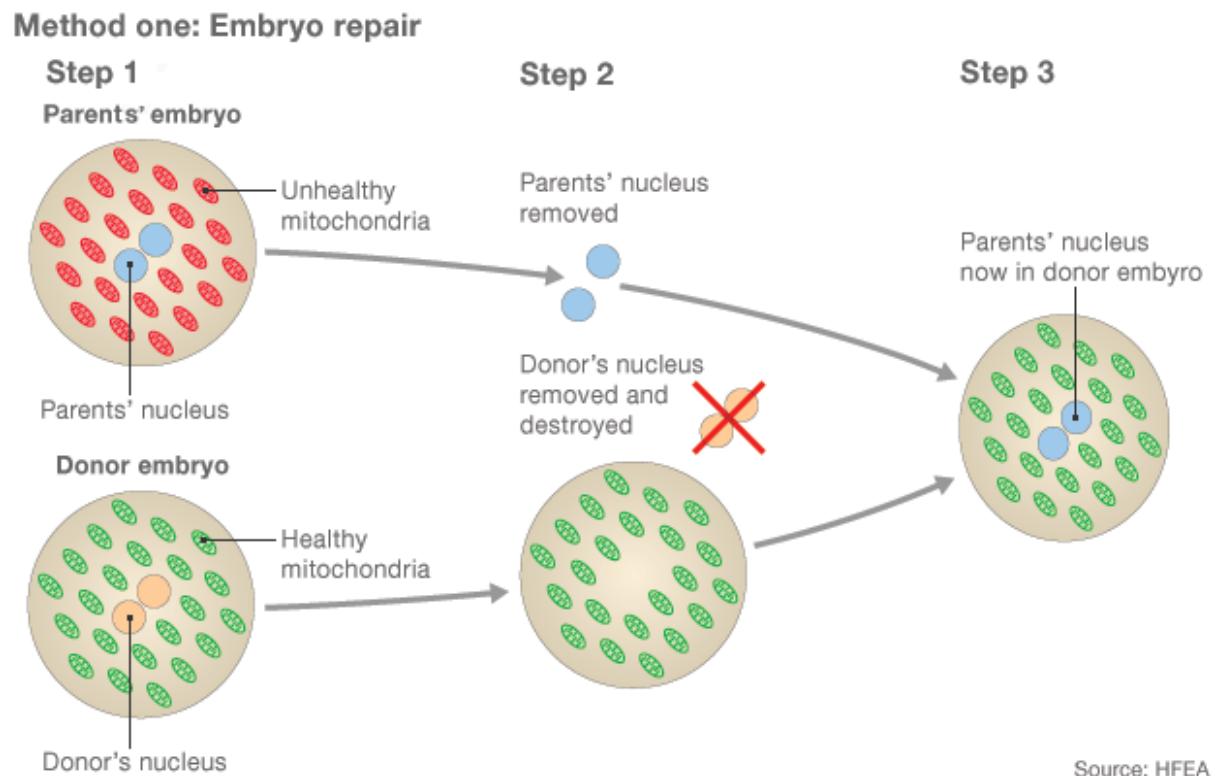
Tottenham Hotspur v  
Southampton: Premier  
League - live!



Police seek 33-year-old  
man in connection with

# Sex

- Mitochondrial replacement therapy (MRT)
- Prevent inheritance of mitochondrial disorders
- Legalized Britain 2015
- Dec 15, 2016 approved by UK's Human Fertilisation and Embryology Authority



# nature Human history

International weekly journal of science

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NATURE | NEWS

## Neanderthal tooth plaque hints at meals — and kisses

Analysis paints picture of diets, medicine and possible intimacy with humans.

Ewen Callaway

08 March 2017

[PDF](#) [Rights & Permissions](#)



A painting of a Neanderthal sitting by a campfire, eating from a bowl. Two other Neanderthals are visible in the background near the fire.

**Palm up**



A photograph showing a person's legs and feet as they walk through a field of oil palm trees, harvesting fruit.

**A makeover for the world's most hated crop**

Oil palm has a reputation as an environmental menace. Can the latest genetic research change that?

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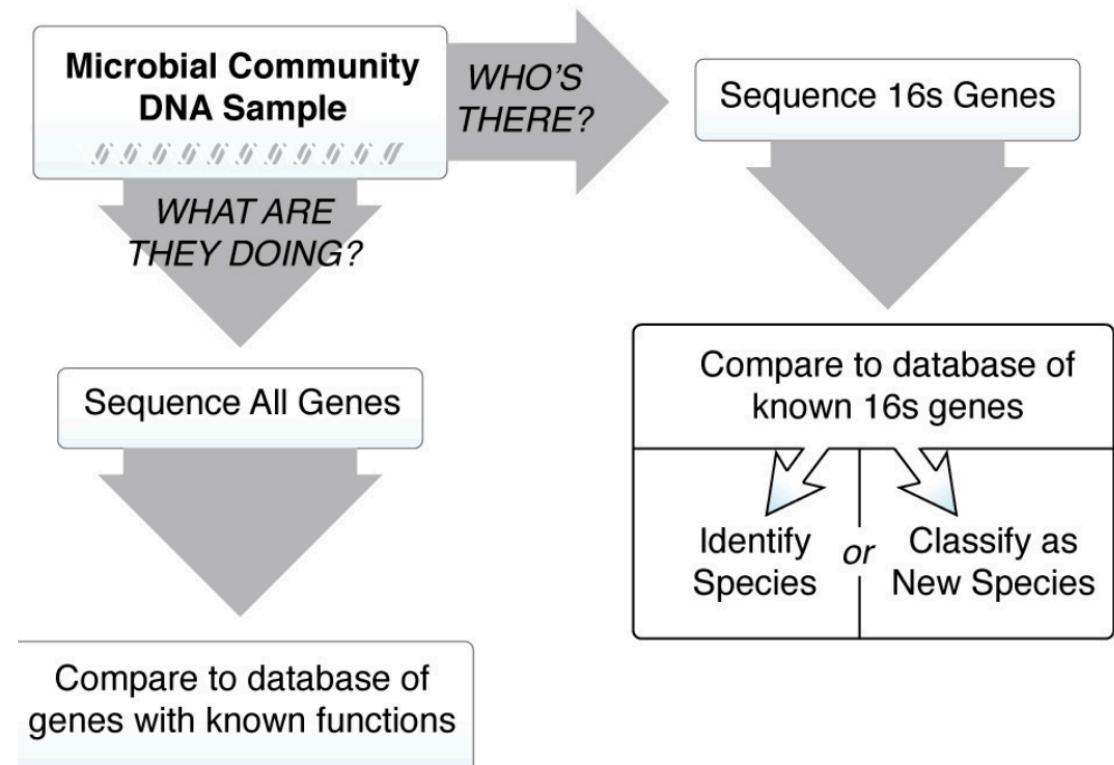
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# Rock 'n Roll

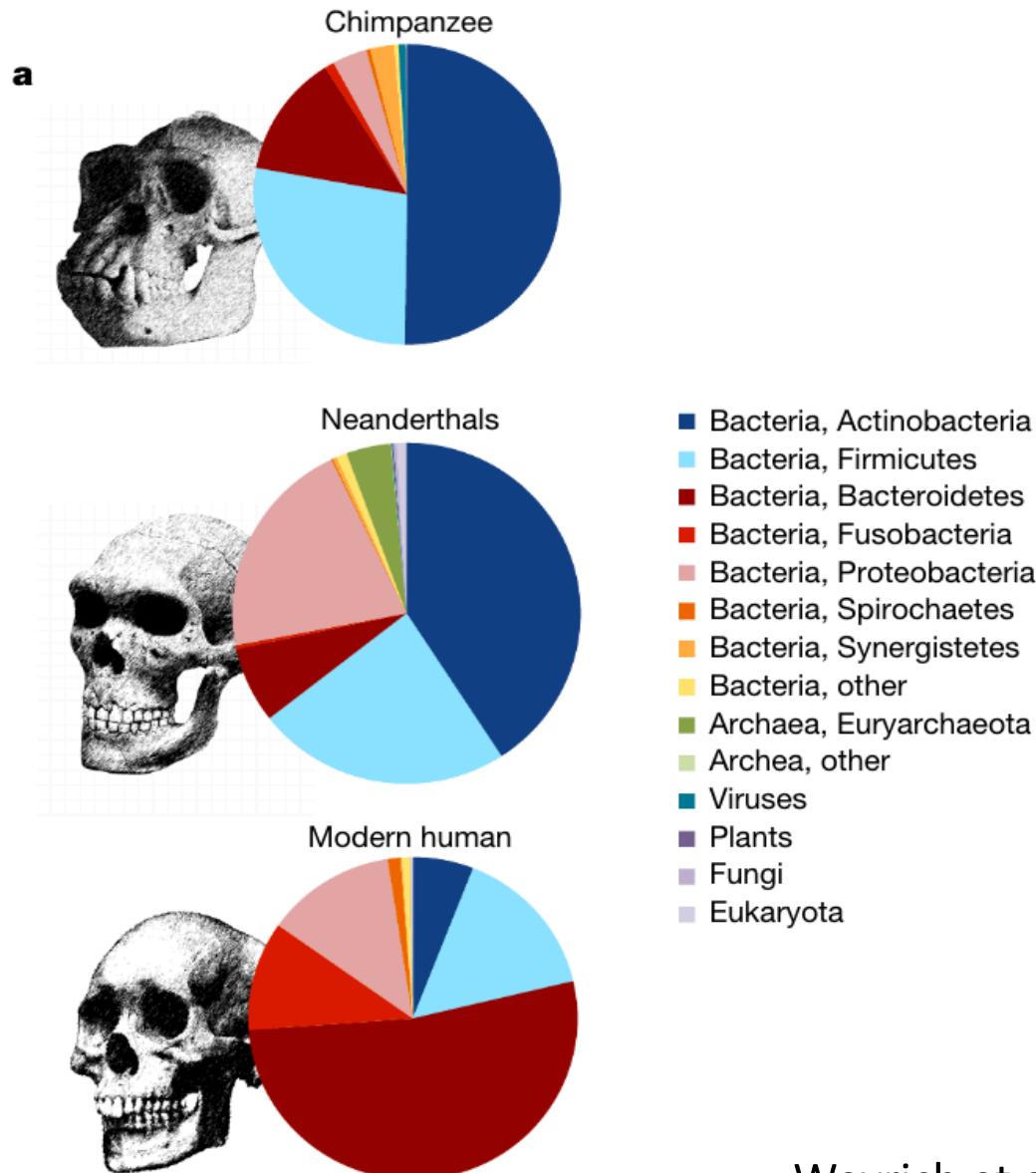
- Fossilized ancient DNA
- Teeth microbiome



<http://learn.genetics.utah.edu/content/microbiome/ecosystem/>

# Metagenomics

- Bacterial composition
- Diet
- Sex



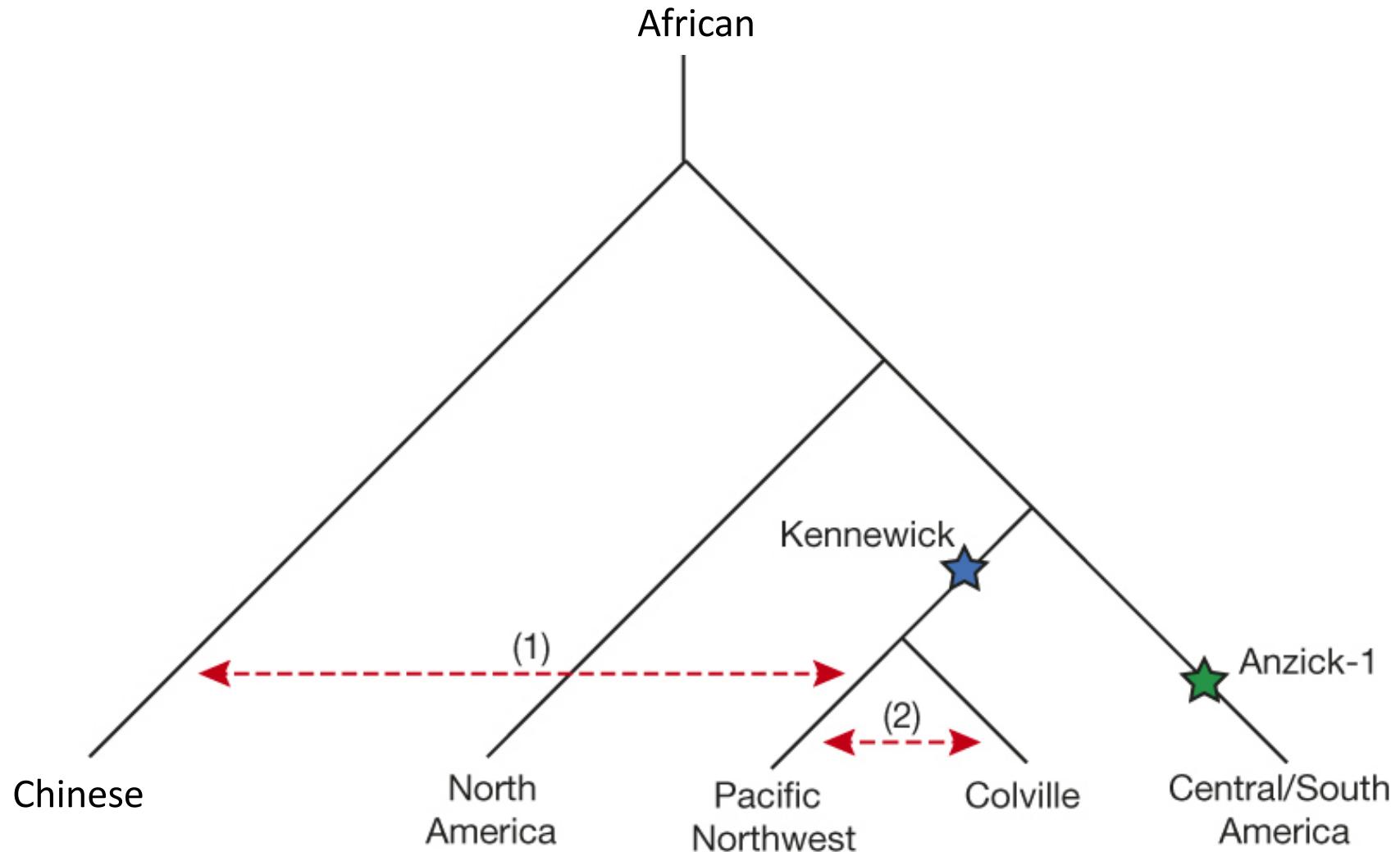
# Forensics, ancestry

- Kennewick Man, the “Ancient One”
  - Discovered 1996
  - Columbia Riverbed, Kennewick, Washington
  - Dated to ~9,000 years ago
- Cranial morphology was used to initially reject ancestry
  - 5 tribes claim ancestry
  - Confederated Tribes of the Colville Reservation (Colville)



Chip Clark  
Smithsonian's National Museum of Natural History

# Comparative genomics



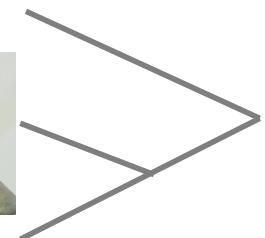
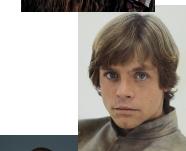
# Comparative genomics exercise

count number informative positions  
infer sequence similarity A closer to B or C?

Sequence A **GATCTATCTCAGAGTCTATGC**

Sequence B **GATCTTTCTCCGACTCTAAAGC**

Sequence C **GATCTTTCTCCGATTCTAAAGC**



# Synthetic biology



## Synthetic Yeast 2.0

Building the world's first synthetic eukaryotic genome together

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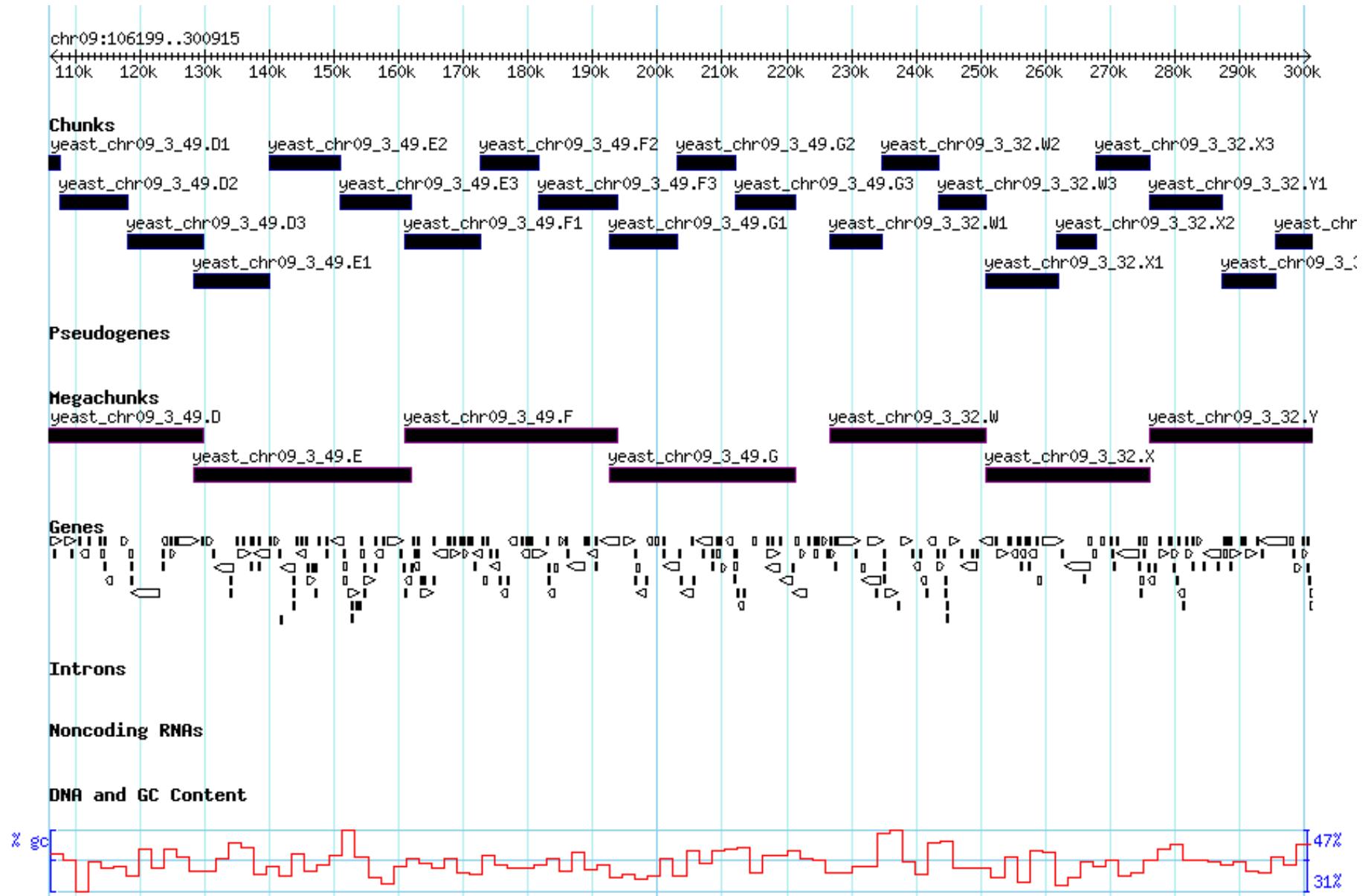
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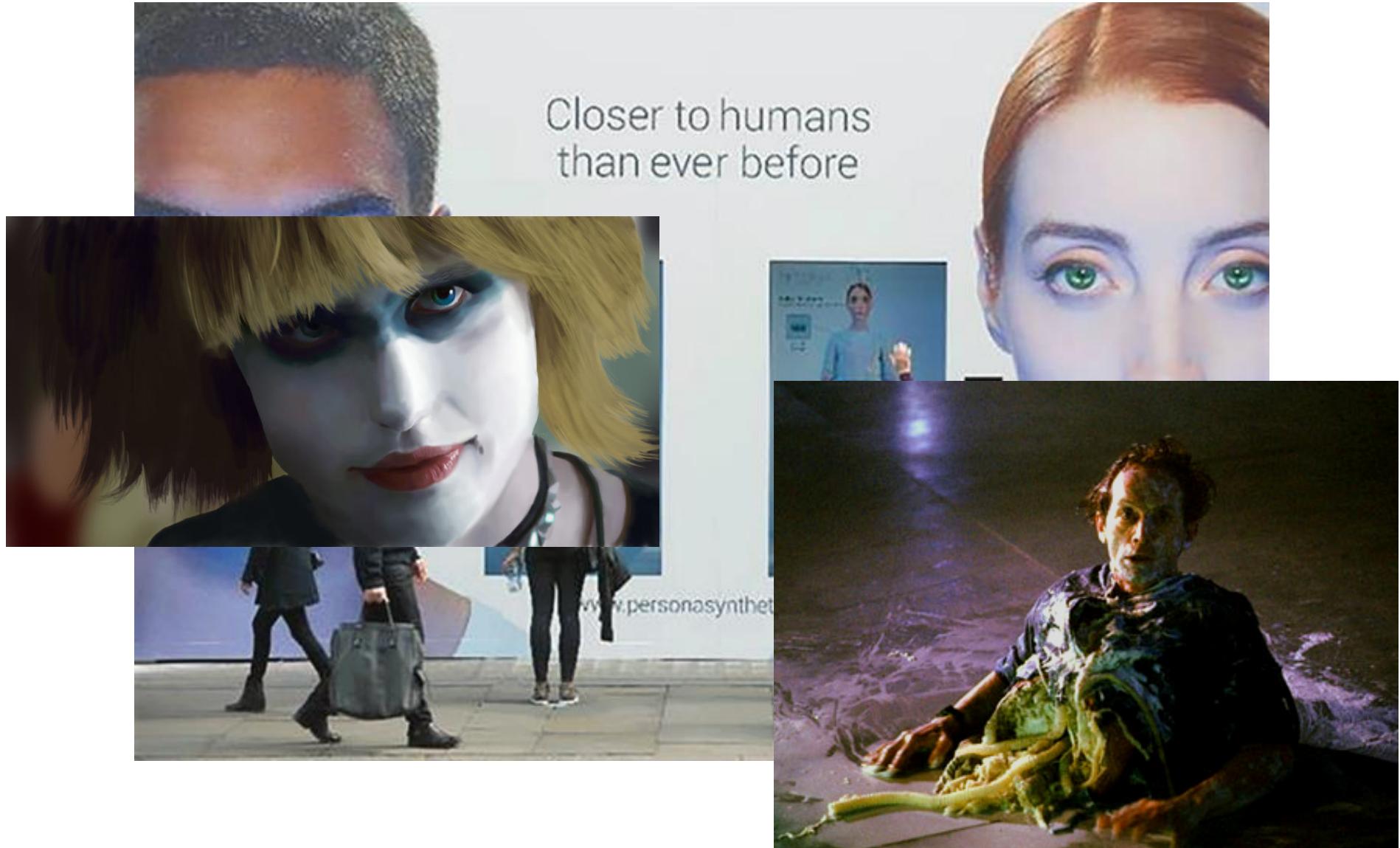
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<http://syntheticyeast.org/sc2-0/>  
genome browser

# SC2.0 Genome Browser



# Why synthetic genomes?





<http://www.ex-astris-scientia.org/inconsistencies/refguide/tricorder-thesquireofgothos.jpg>

# The future of sequencing...

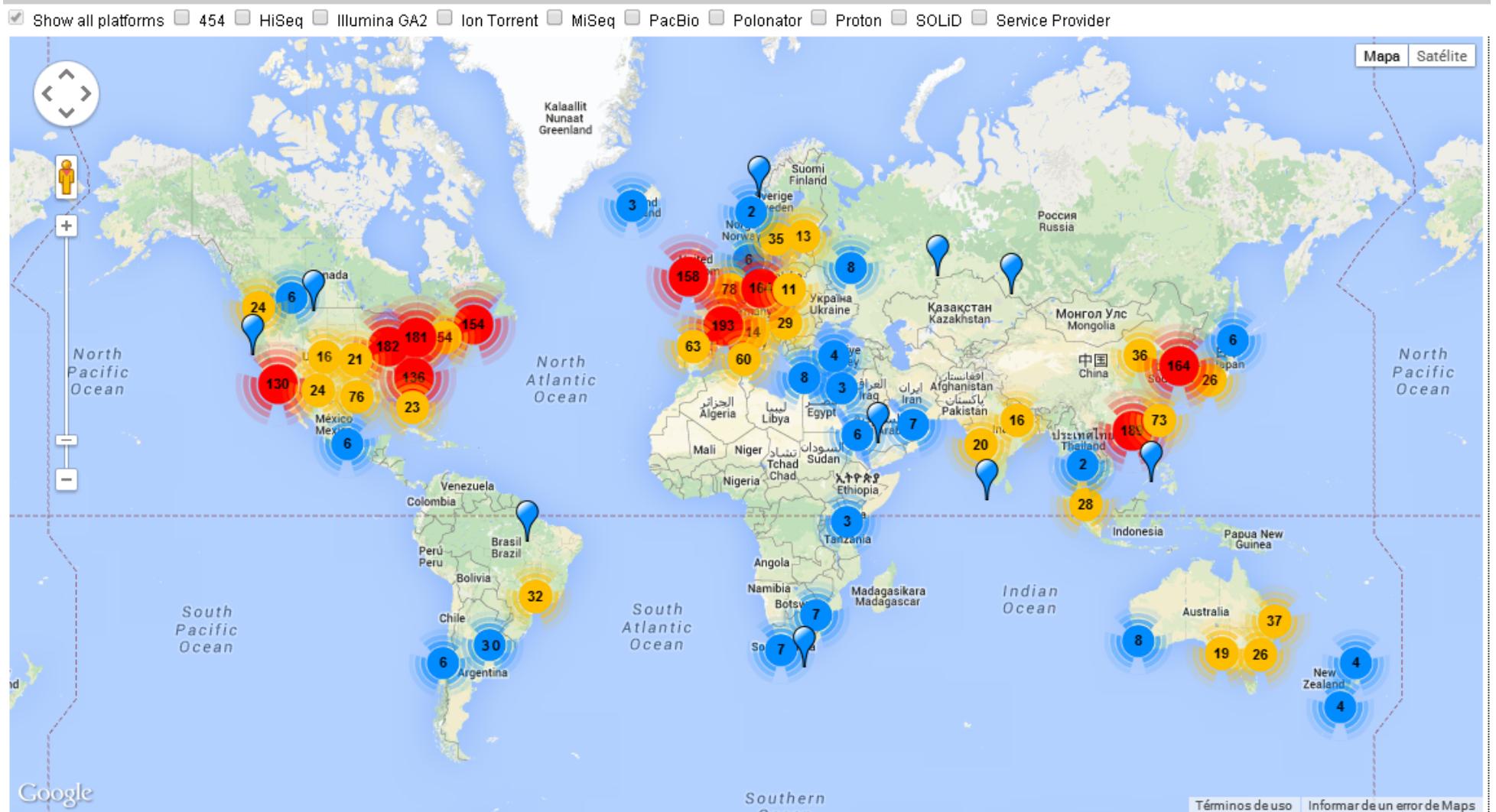


*Tiny SmidgION is currently in early-stage development*

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# Sequencing across the world

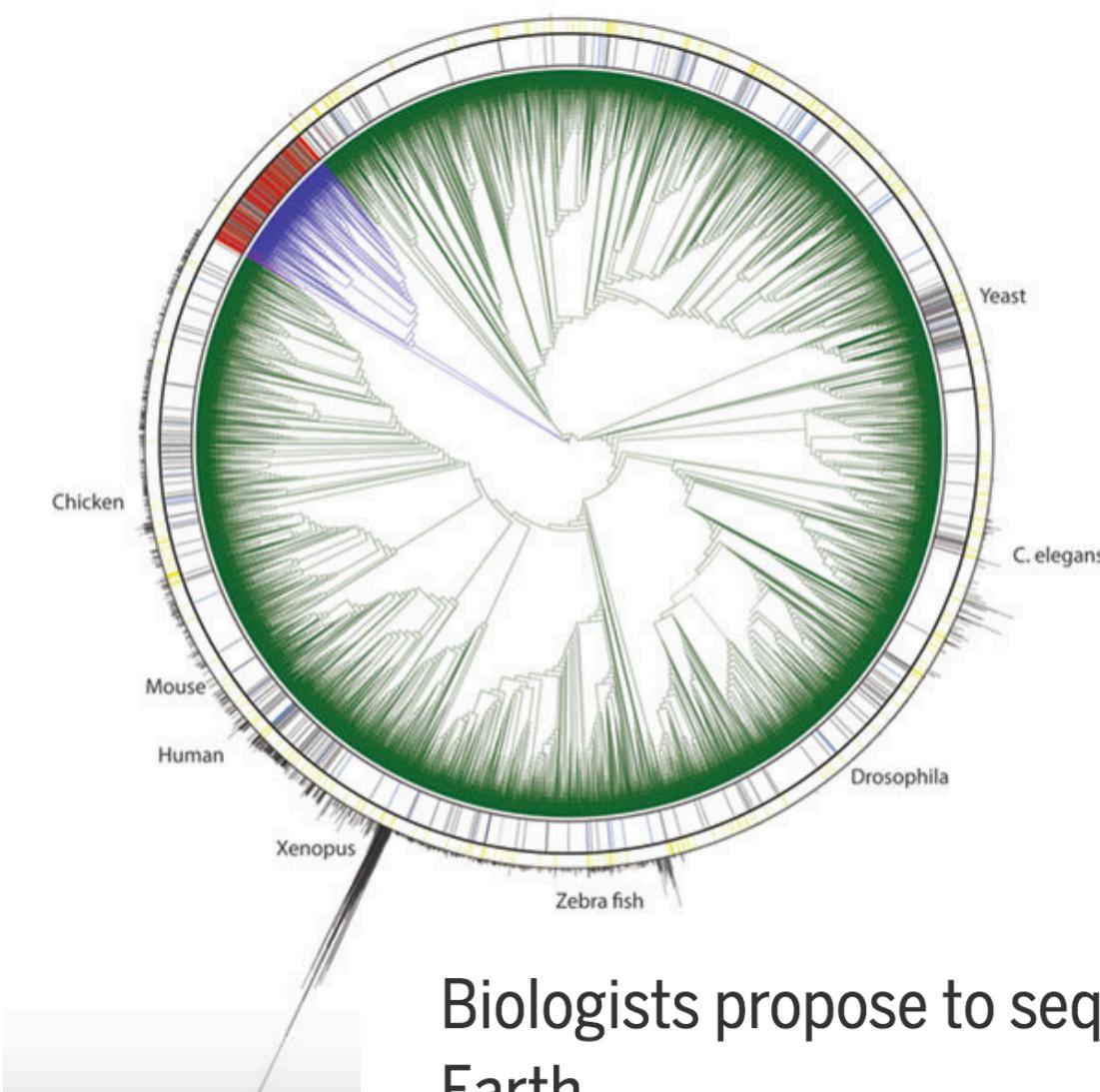


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# Earth Biogenome Project



green = eukaryotes  
blue = bacteria  
purple = archaea  
red = sequenced genomes

Biologists propose to sequence the DNA of all life on Earth

## Whanganui River given legal status of a person under unique Treaty of Waitangi settlement

By Isaac Davison - [Wanganui Chronicle](#)

10:53 PM Wednesday Mar 15, 2017

 21 comments

History

Manawatu-Whanganui

Maori

New Zealand

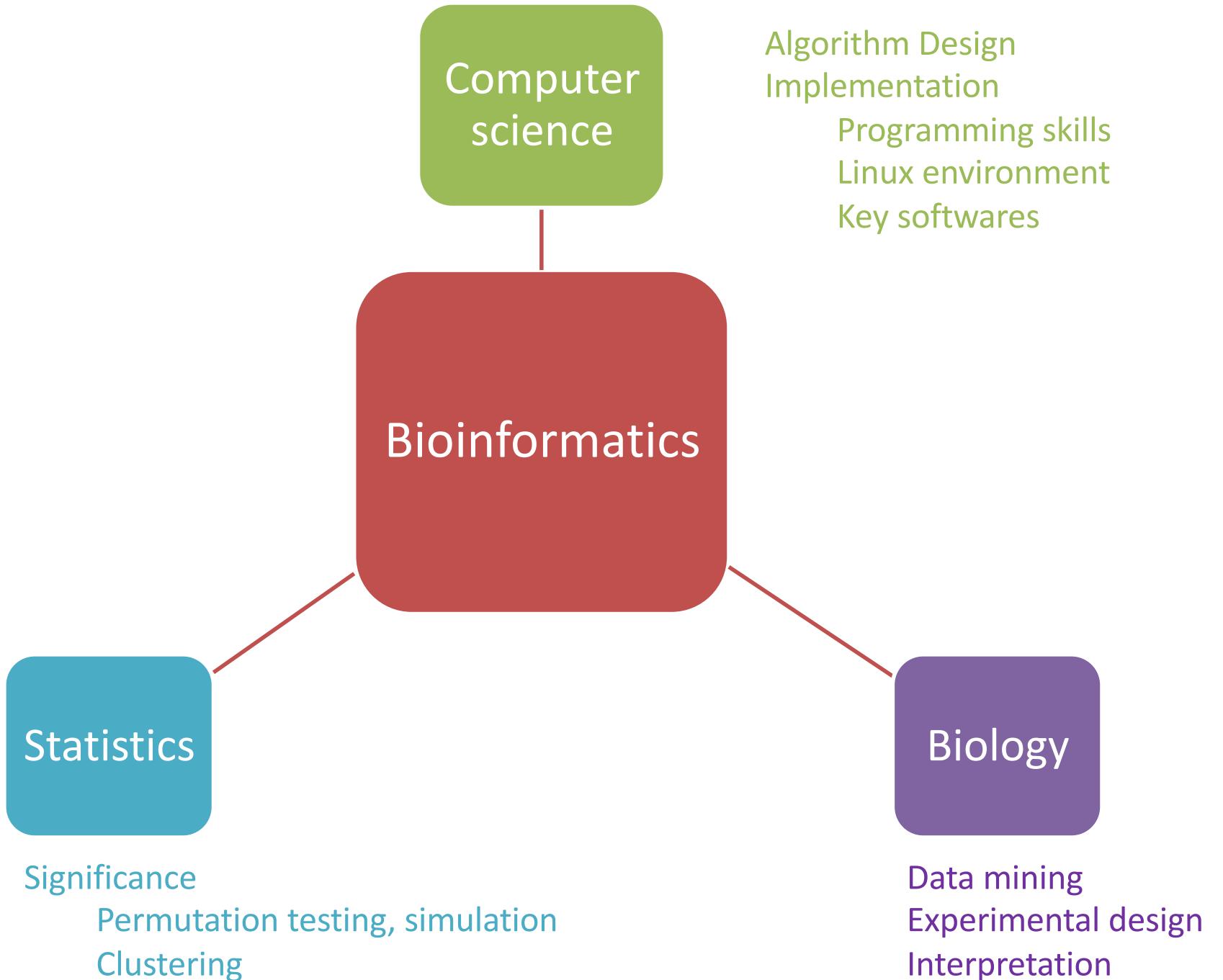
...

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# Summary and take-home messages

- Goals for today
  - Understand the difference genetics V genomics
  - Survey specific applications of genomics in biology
  - Introduce tools and concepts of genomic analysis
- Next class – in lab tutorial
  - Treating genomes as coordinates
  - Comparing genomic sequence features
- Moving forward
  - Genomics technologies
  - Theory: from strings to assemblies
  - Practical applications of tools for bioinformatics



# How do we interrogate genomes?

The screenshot shows the Galaxy web interface at <https://usegalaxy.org>. The main content area displays the Galaxy homepage with the heading "Try Galaxy on the Cloud" and the subtext "Now you can have a personal Galaxy within the infinite Universe". To the left is a sidebar titled "Tools" containing a search bar and a list of tool categories. The top navigation bar includes links for "Analyze Data", "Workflow", "Shared Data", "Visualization", "Help", "User", and a grid icon. The right side features a "History" panel listing imported datasets and their details, such as "Galaxy 101 NGS Variant" and various processing steps involving BWA and FastQC.

Galaxy is an open source, web-based platform for data intensive biomedical research. If you are new to Galaxy [start here](#) or consult our [help resources](#). You can install your own Galaxy by following the [tutorial](#) and choose from thousands of tools from the [Tool Shed](#).

Try Galaxy on the Cloud

Now you can have a personal Galaxy within the infinite Universe

History

- imported: Galaxy 101 NGS Variant  
21 shown  
313.43 MB
- 10: Filter SAM on data 6
- 9: Filter SAM on data 7
- 8: Map with BWA for Illumina on data 4 and data 3: mapped reads
- 7: Map with BWA for Illumina on data 2 and data 1: mapped reads
- 6: FastQC\_raw\_child-ds-2.fq.html
- 5: FastQC\_raw\_child-ds-1.fq.html
- 4: raw\_mother-ds-2.fq

# Key concepts/Terminology

- Genetics
- Genomics
- Bioinformatics
- Alignment
- Homology
- Orthology
- Phylogeny
- Parsimony
- Microbiome
- Metagenomics
- CLI
- GUI

<https://ekviky.github.io/genomics-intro/>

# Appendix