

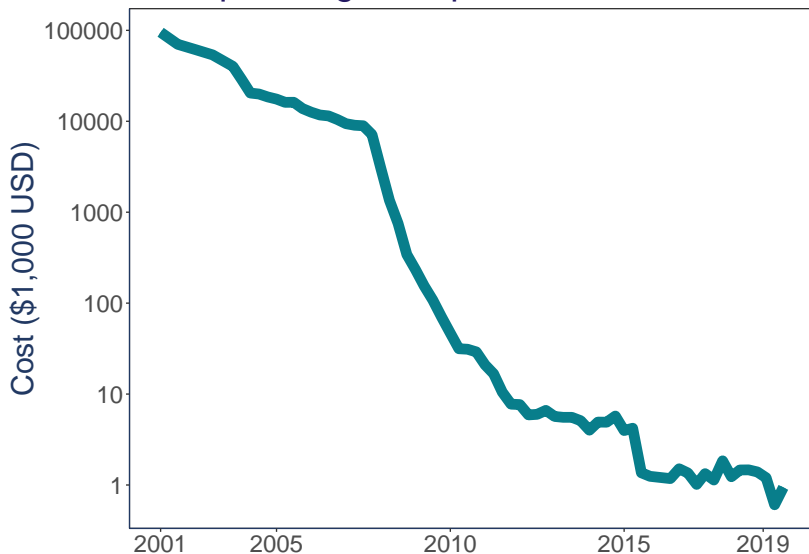
Bioinformatics: the hot interdisciplinary field

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Sequencing Cost per Human Genome

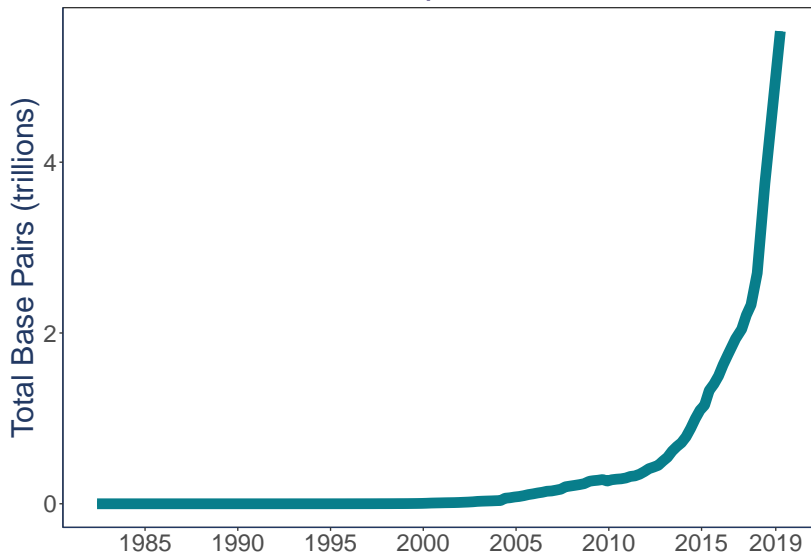


adapted from: Kris Wetterstrand, National Human Genome Research Institute

Cost to Sequence a Human Genome in 2019



EMBL Sequence Data



Data from: EMBL

How many GB is that?

All that sequence data would equal about

11,066,077,343,692 GB

How many GB is that?



\approx **512GB**



22 BILLION LAPTOPS

Bioinformatics to the rescue!



What is Bioinformatics?

Bioinformatics is taking **biological data, processes and theories** and **applying** “informatics” techniques (derived from disciplines like **math, computer science, and statistics**) to understand, organize, and predict biological processes.

1. Data Analysis
2. Software Development
3. Modeling
4. Combination

1. Data Analysis
2. Software Development
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**Generating, interpreting,
and explaining any
biological data**

1. Data Analysis

Building the Human Genome



1989: The Banbury meeting at Cold Spring Harbor Laboratory in New York before the launch of the Human Genome Project.

The Human Genome is Sequenced!

International Human Genome Sequencing Consortium Announces
“Working Draft” of Human Genome, June 2000

1. Data Analysis

The Human Genome is Sequenced...Again!

1. Data Analysis

The Human Genome is Sequenced...Again!



February 2001

1. Data Analysis

The Human Genome is Sequenced...yet AGAIN!

1. Data Analysis

The Human Genome is Sequenced...yet AGAIN!

The complete Human Genome is announced by NHGRI

**But is the human genome
really “Complete”?**

1. Data Analysis
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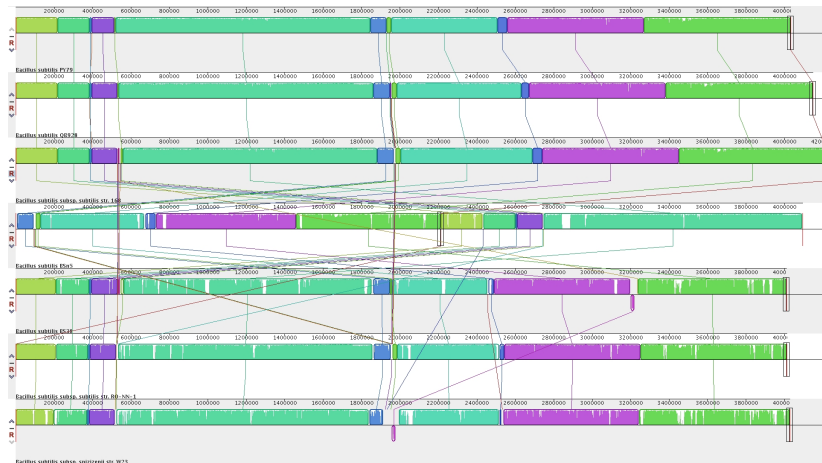
**Creating bioinformatics
tools for other people to
use**

2. Software Development

`progressiveMauve`: Whole genome alignment program

2. Software Development

progressiveMauve: Whole genome alignment program



2. Software Development

progressiveMauve: Whole genome alignment program

```
info@15 Mauve% /home/dlato/Mauve_snapshot/mauve_snapshot_2012-06-07/linux-x64/progressiveMauve --help
/home/dlato/Mauve_snapshot/mauve_snapshot_2012-06-07/linux-x64/progressiveMauve: unrecognized option '--help'
progressiveMauve usage:

When each genome resides in a separate file:
/home/dlato/Mauve_snapshot/mauve_snapshot_2012-06-07/linux-x64/progressiveMauve [options] <seq1 filename> ... <seqN filename>

When all genomes are in a single file:
/home/dlato/Mauve_snapshot/mauve_snapshot_2012-06-07/linux-x64/progressiveMauve [options] <seq filename>

Options:
--island-gap-size=number Alignment gaps above this size in nucleotides are considered to be islands [20]
--profile=file (Not yet implemented) Read an existing sequence alignment in XMA format and align it to other sequences or alignments
--apply-backbone=file Read an existing sequence alignment in XMA format and apply backbone statistics to it
--disable-backbone Disable backbone detection
--mum Find MUMs only, do not attempt to determine locally collinear blocks (LCBs)
--seed-weight=number Use the specified seed weight for calculating initial anchors
--output=file Output file name. Prints to screen by default
--backbone-output=file Backbone output file name (optional)
--match-input=file Use specified match file instead of searching for matches
--input-id-matrix=file An identity matrix describing similarity among all pairs of input sequences/alignments
--max-gapped-aligner-length=number Maximum number of base pairs to attempt aligning with the gapped aligner
--input-guide-tree=file A phylogenetic guide tree in NEWICK format that describes the order in which sequences will be aligned
--output-guide-tree=file Write out the guide tree used for alignment to a file
--version Display software version information
--debug Run in debug mode (perform internal consistency checks--very slow)
--scratch-path=[-path] Designate a path that can be used for temporary data storage. Two or more paths should be specified.
--scratch-path=[-path] Designate a path that can be used for temporary data storage. Two or more paths should be specified.
--collinear Assume that input sequences are collinear--they have no rearrangements
--scoring-scheme=ancestral|sp ancestral|sp Selects the anchoring score function. Default is extant sum-of-pairs (sp).
--no-weight-scaling Don't scale LCB weights by conservation distance and breakpoint distance
--max-breakpoint-distance=number [0..1] Set the maximum weight scaling by breakpoint distance. Defaults to 0.5
--conservation-distance-scale=number [0..1] Scale conservation distances by this amount. Defaults to 0.5
--muscle-args=arguments in quotes Additional command-line options for MUSCLE. Any quotes should be escaped with a backslash
--skip-refinement Do not perform iterative refinement
--skip-gapped-alignment Do not perform gapped alignment
--bp-dist-estimate-min-score=number Minimum LCB score for estimating pairwise breakpoint distance
--mem-clean Set this to true when debugging memory allocations
--gap-open=number Gap open penalty
--repeat-penalty=negative|zero Sets whether the repeat scores go negative or go to zero for highly repetitive sequences. Default is negative.
--gap-extend=number Gap extend penalty
--substitution-matrix=file Nucleotide substitution matrix in NCBI format
--weight=number Minimum pairwise LCB score
--min-scaled-penalty=number Minimum breakpoint penalty after scaling the penalty by expected divergence
--hmm-p-go-homologous=number Probability of transitioning from the unrelated to the homologous state [0.00001]
--hmm-p-go-unrelated=number Probability of transitioning from the homologous to the unrelated state [0.000000001]
--hmm-identity=number Expected level of sequence identity among pairs of sequences, ranging between 0 and 1 [0.7]
--seed-family Use a family of spaced seeds to improve sensitivity
--solid-seeds Use solid seeds. Do not permit substitutions in anchor matches.
--coding-seeds Use coding pattern seeds. Useful to generate matches coding regions with 3rd codon position degeneracy.
--disable-cache Disable recursive anchor search caching to workaround a crash bug
--no-recursion Disable recursive anchor search

Examples:
/home/dlato/Mauve_snapshot/mauve_snapshot_2012-06-07/linux-x64/progressiveMauve --output=my_seqs.xma my_genome1.gbk my_genome2.gbk my_genome3.fasta

If genomes are in a single file and have no rearrangement:
/home/dlato/Mauve_snapshot/mauve_snapshot_2012-06-07/linux-x64/progressiveMauve --collinear --output=my_seqs.xma my_genomes.fasta

info@15 Mauve% █
```

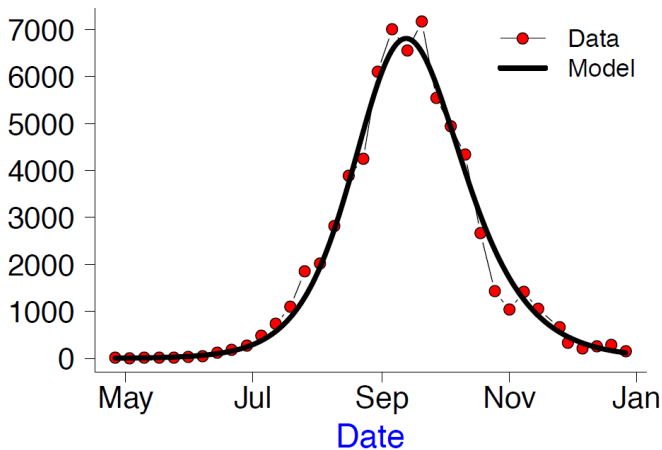
1. Data Analysis
2. Software Development
3. Modeling
4. Combination

Using mathematical and statistical principals to represent and predict biological systems or data

3. Modelling

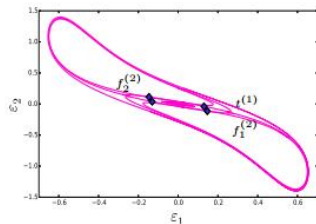
SIR model and the Great Plague of London

Weekly Deaths from Plague

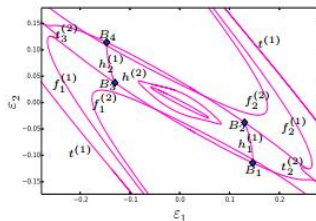


3. Modelling

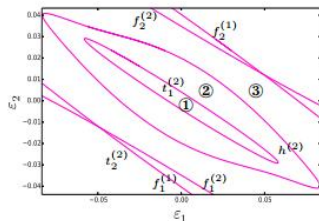
Bifurcation theory and predator-prey relationships



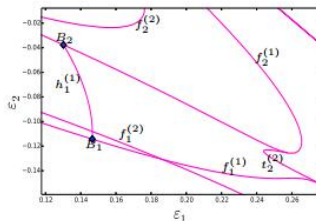
(A)



(B)



(C)



(D)

Li et al. 2018, from Gail Wolkowicz's lab at McMaster University

1. Data Analysis
2. Software Development
3. Modeling
4. Combination

4. Combination

- Modelling + Software Development
- Data Analysis + Modelling
- Data Analysis + Software Development
- Data Analysis + Modelling + Software Development

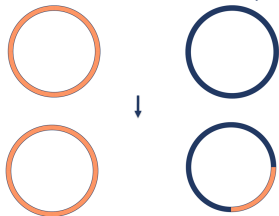
Spatial Patterns of Molecular Trends in Bacterial Genomes

(How do molecular trends change with position in the genome?)

Bacteria are bizarre!

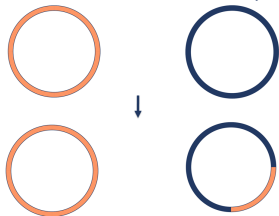
Bacteria are bizarre!

Horizontal Gene Transfer (HGT)

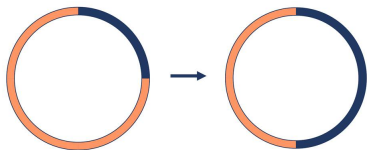


Bacteria are bizarre!

Horizontal Gene Transfer (HGT)

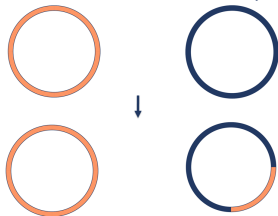


Duplication

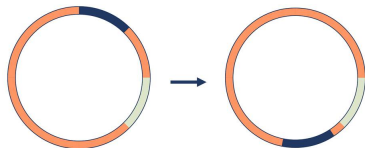


Bacteria are bizarre!

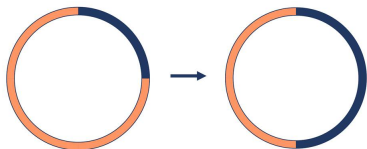
Horizontal Gene Transfer (HGT)



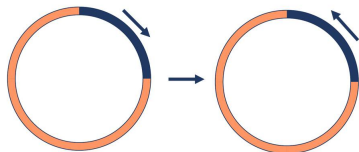
Rearrangement and Translocation



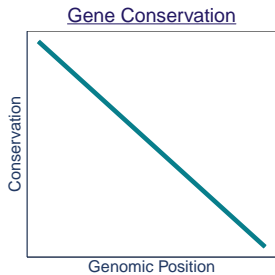
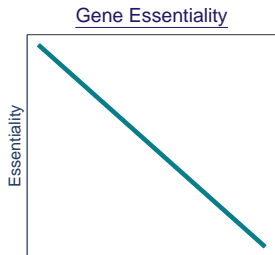
Duplication



Inversion

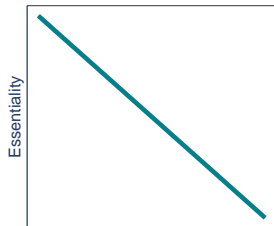


My Research: Spatial molecular trends

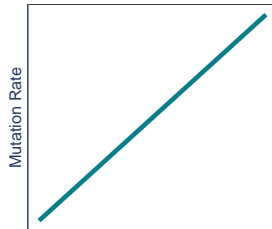


My Research: Spatial molecular trends

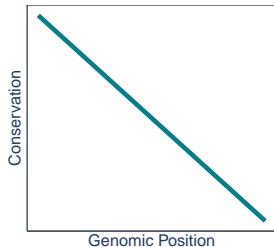
Gene Essentiality



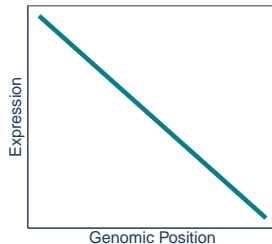
Mutation Rate



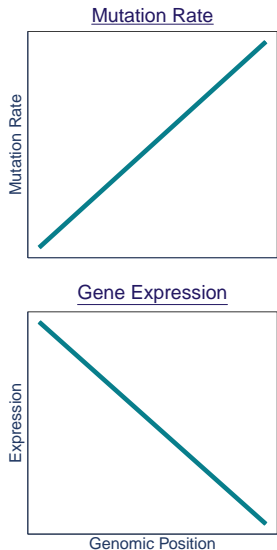
Gene Conservation



Gene Expression



My Research: Spatial molecular trends



Couturier et al. 2006, Cooper et al. 2010, Sharp et al. 2005, Morrow et al. 2012, Cooper and Rocha 2006

My Research: The Organisms

Bacteria:

- *Escherichia coli*
- *Bacillus subtilis*
- *Streptomyces*
- *Sinorhizobium meliloti*

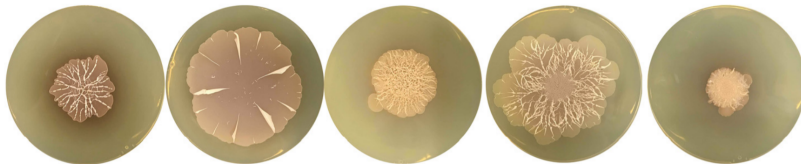
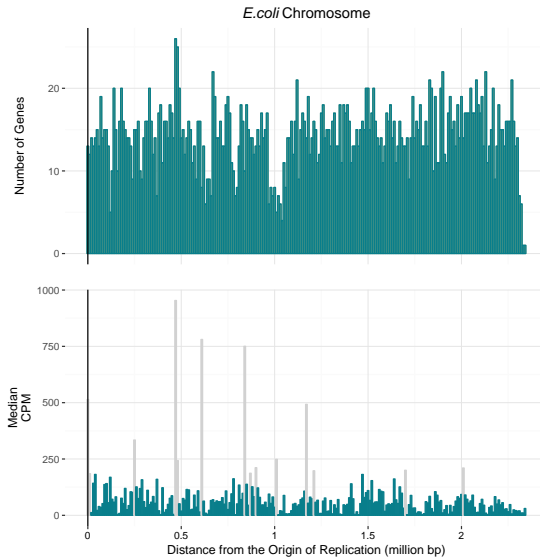
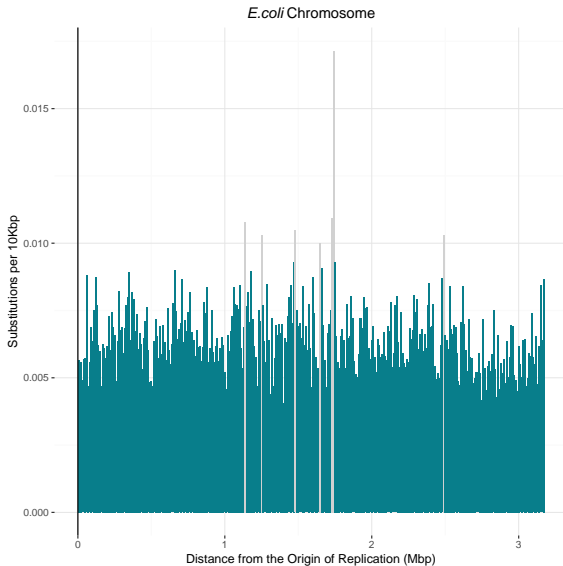


Photo: *Streptomyces* by Stephanie Jones, Marie Elliot's Lab at McMaster University

My Research: Gene Expression

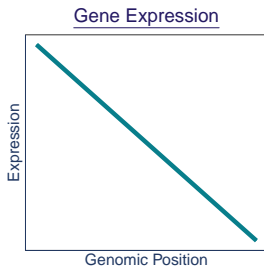
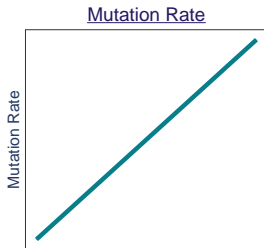


My Research: Substitutions

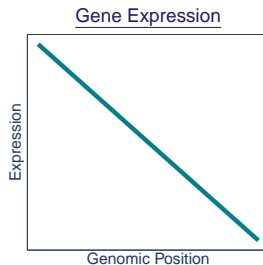
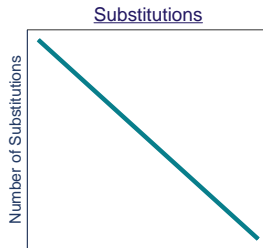


My Research: Conclusions

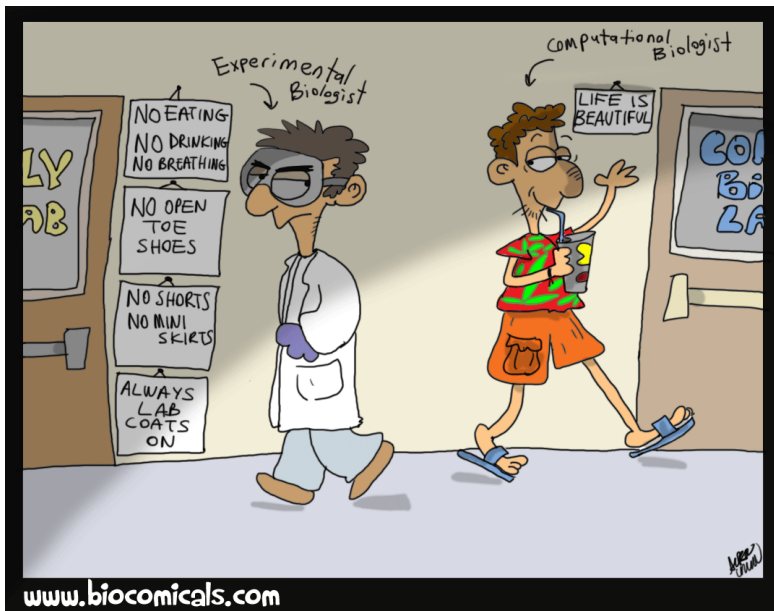
Previous Studies:



My Research:



Why become a Comp Bio Geek?



Courses you should take or audit:

- **Bio 3S03:** Intro to Bioinformatics
- **Bio 3SS3:** Population Ecology
- **Math 4MB3:** Mathematical Biology
- **Math 3MB3:** Introduction to Modelling
- suggestions??

Questions?

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