

# Welcome to Bacterial Population Genomics!

Introductions – Name, Academic Stage, Research Interests, Goal for this seminar

## Introductory Concepts

- Bacterial diversity, evolution and ecology in relation to hosts
- Genomes, HGT and the “pan-genome”
- Biogeography
- Local adaptation

Resource Introduction: command line & kamiak accounts

# Origin of Bacteria

Universe begins  
with Big Bang  
16 billion  
years ago



Solar System  
condenses  
from interstellar  
dust cloud



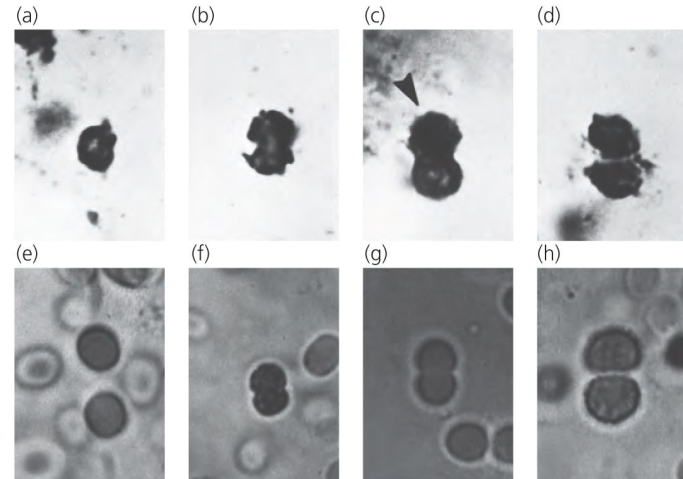
Earth forms  
4.5 billion  
years ago



Oldest  
terrestrial  
rocks  
4.3 billion  
years ago



Heavy  
bombardment  
ends 4 billion  
years ago



3.26 BYA fossil from S. Africa (top)

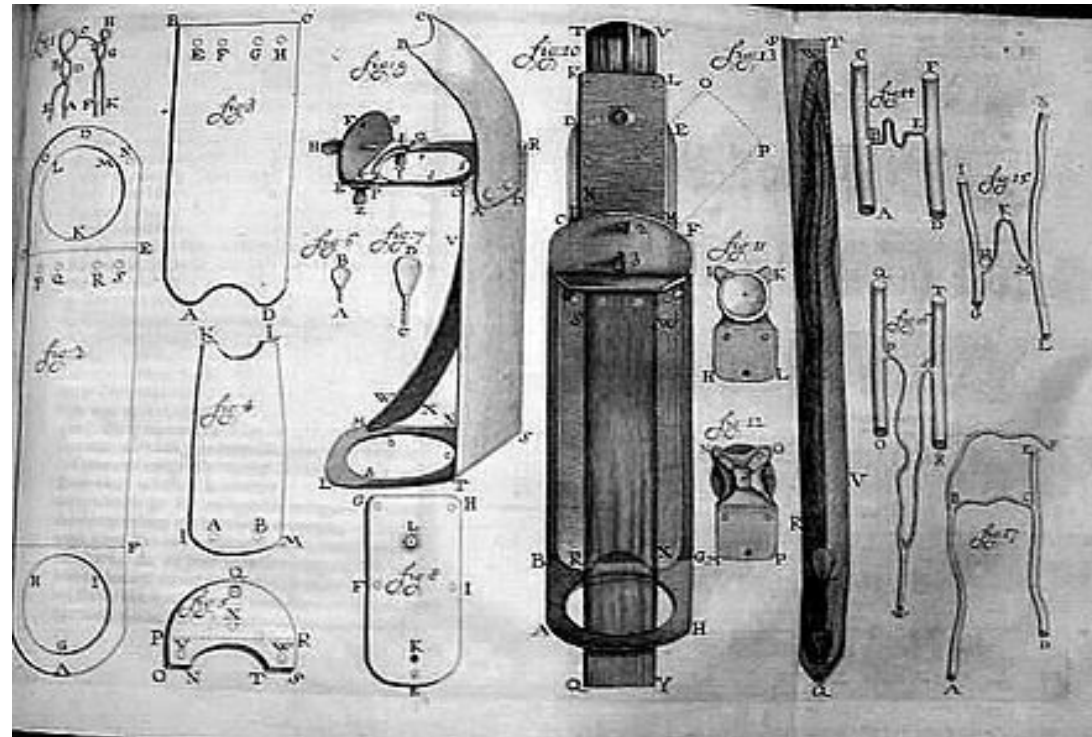
Modern bacteria (bottom)

2.5 BYA: Oxygen accumulates

1.5 BYA First Eukaryotes

500MYA Multicellular Diversification

# Antonie van Leeuwenhoek (Dutch scientist)



# Louis Pasteur (French microbiologist)



# Robert Koch (German physician)



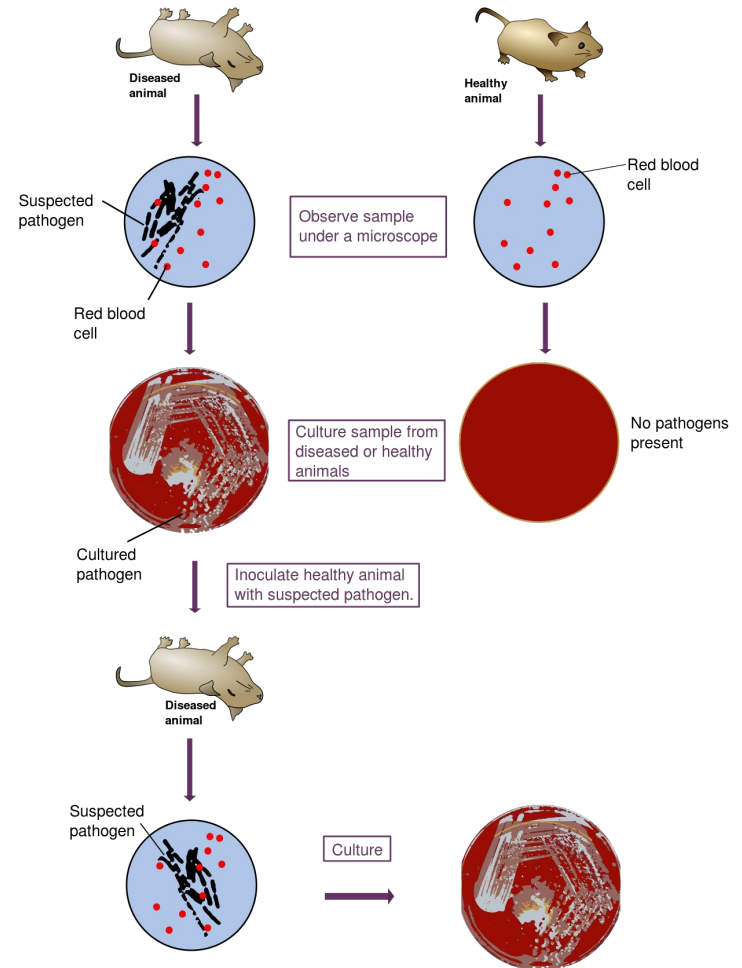
## Koch's Postulates:

① The microorganism must be found in abundance in all organisms suffering from the disease, but should not be found in healthy organisms.

② The microorganism must be isolated from a diseased organism and grown in pure culture.

③ The cultured microorganism should cause disease when introduced into a healthy organism.

④ The microorganism must be reisolated from the inoculated, diseased experimental host and identified as being identical to the original specific causative agent.





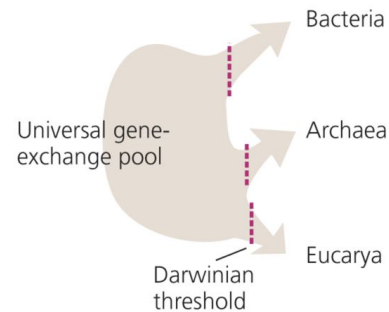
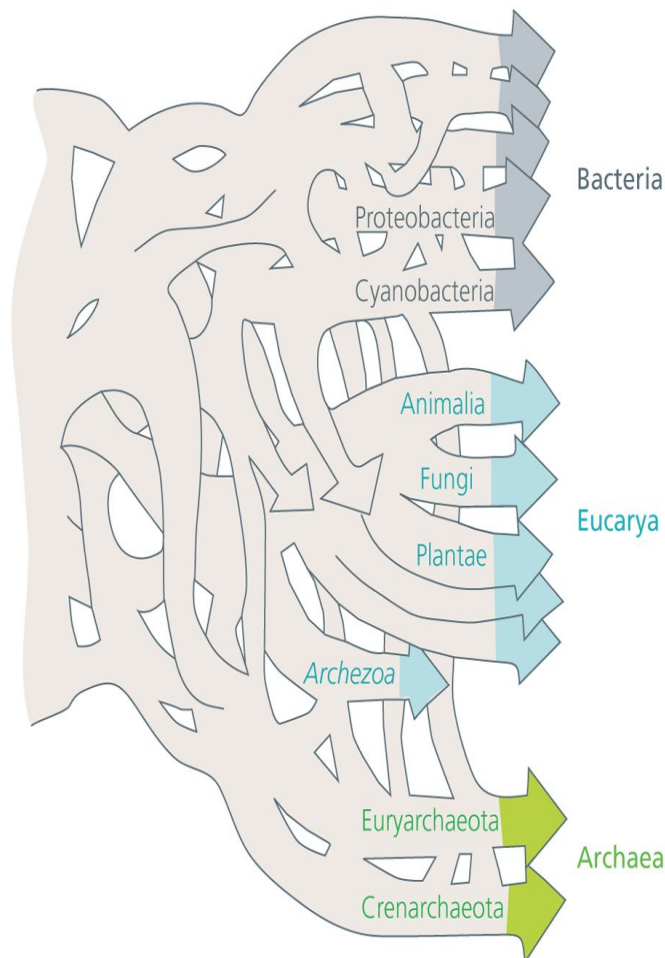
# Carl Woese

ribosomal tree of life



	1	2	3	4	5	6	7	8	9	10	11	12	13
1. <i>Saccharomyces cerevisiae</i> , 18S	—	0.29	0.33	0.05	0.06	0.08	0.09	0.11	0.08	0.11	0.11	0.08	0.08
2. <i>Lemna minor</i> , 18S	0.29	—	0.36	0.10	0.05	0.06	0.10	0.09	0.11	0.10	0.10	0.13	0.07
3. L cell, 18S	0.33	0.36	—	0.06	0.06	0.07	0.07	0.09	0.06	0.10	0.10	0.09	0.07
4. <i>Escherichia coli</i>	0.05	0.10	0.06	—	0.24	0.25	0.28	0.26	0.21	0.11	0.12	0.07	0.12
5. <i>Chlorobium vibrioforme</i>	0.06	0.05	0.06	0.24	—	0.22	0.22	0.20	0.19	0.06	0.07	0.06	0.09
6. <i>Bacillus firmus</i>	0.08	0.06	0.07	0.25	0.22	—	0.34	0.26	0.20	0.11	0.13	0.06	0.12
7. <i>Corynebacterium diphtheriae</i>	0.09	0.10	0.07	0.28	0.22	0.34	—	0.23	0.21	0.12	0.12	0.09	0.10
8. <i>Aphanocapsa</i> 6714	0.11	0.09	0.09	0.26	0.20	0.26	0.23	—	0.31	0.11	0.11	0.10	0.10
9. Chloroplast ( <i>Lemna</i> )	0.08	0.11	0.06	0.21	0.19	0.20	0.21	0.31	—	0.14	0.12	0.10	0.12
10. <i>Methanobacterium thermoautotrophicum</i>	0.11	0.10	0.10	0.11	0.06	0.11	0.12	0.11	0.14	—	0.51	0.25	0.30
11. <i>M. ruminantium</i> strain M-1	0.11	0.10	0.10	0.12	0.07	0.13	0.12	0.11	0.12	0.51	—	0.25	0.24
12. <i>Methanobacterium</i> sp., Cariaco isolate JR-1	0.08	0.13	0.09	0.07	0.06	0.06	0.09	0.10	0.10	0.25	0.25	—	0.32
13. <i>Methanosarcina barkeri</i>	0.08	0.07	0.07	0.12	0.09	0.12	0.10	0.10	0.12	0.30	0.24	0.32	—

# LUCA: Last Universal Common Ancestor

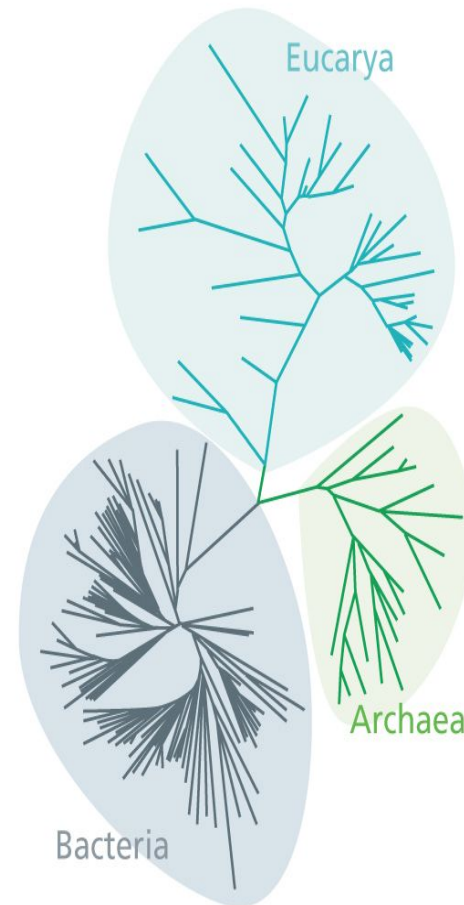
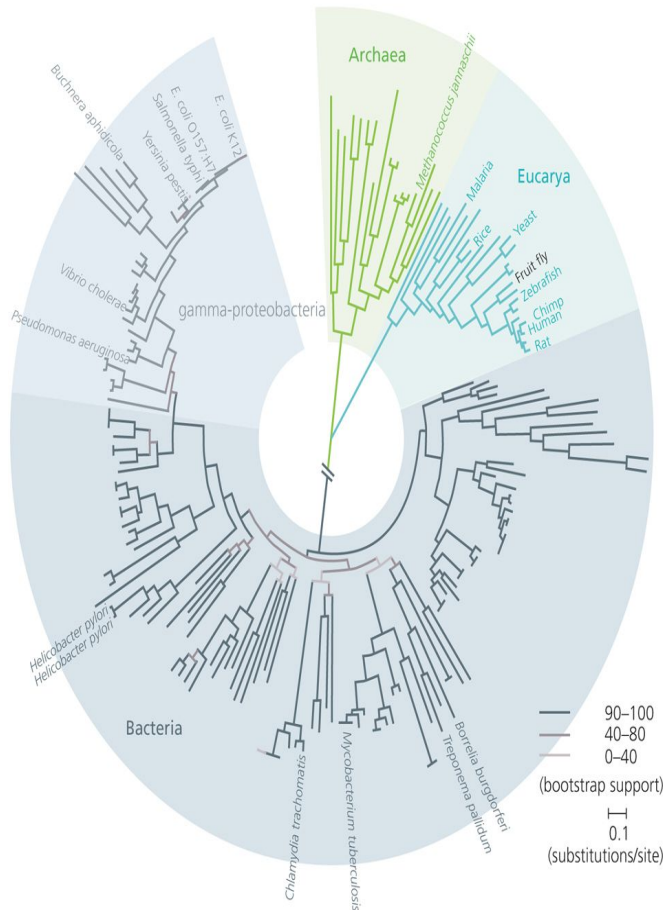


- Carl Woese (originator of 16S universal tree of life) conjectured “communal evolution” early in the tree of life; community trading genes
- However, LUCA as a community is mathematically unstable

# Universal Phylogeny of Life

Based on 31 universal genes

Based on protein super-families





# Bacteria are ancient and very diverse

Some characters:

Peptidoglycan cell wall +/- (gram stain)

Ability to grow with oxygen +/-

Metabolic capabilities:

heterotroph/ oligotroph

(including things like jet fuel),

autotroph (photosynthesis),

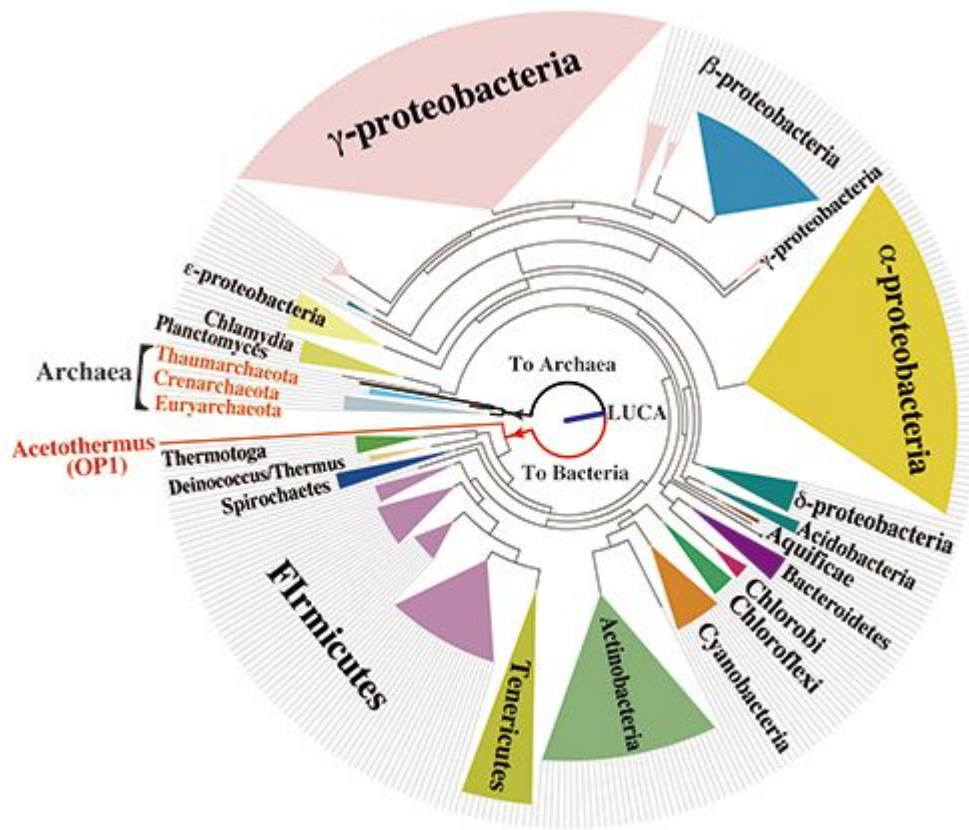
chemi-autotroph (e.g., CO,

sulfide, hydrogen gas, metals)

Thermal, UV, radiation tolerance

Live in rocks, clouds, water, soil,

animals, plants



# Plant-associated Bacteria

## Compartments:

Phyllosphere - bacteria found on above ground portion of plant

Rhizosphere- bacteria found below ground at the plant root and soil interface

Endosphere- bacteria occupying the internal spaces of a plant

## Organisms:

Epiphyte- bacteria which live on the surface of a plant

Endophyte- endosymbiont that lives within plant tissue

Endosymbiont- any organism that lives within another

# Plant-associated Bacteria

Phyllosphere

Rhizosphere

Endosphere

Epiphyte

Endophyte

Endosymbiont

Individually, write down your prediction of how many bacterial cells fall into each category for a single plant.

# Plant-associated Bacteria

Phyllosphere

Rhizosphere

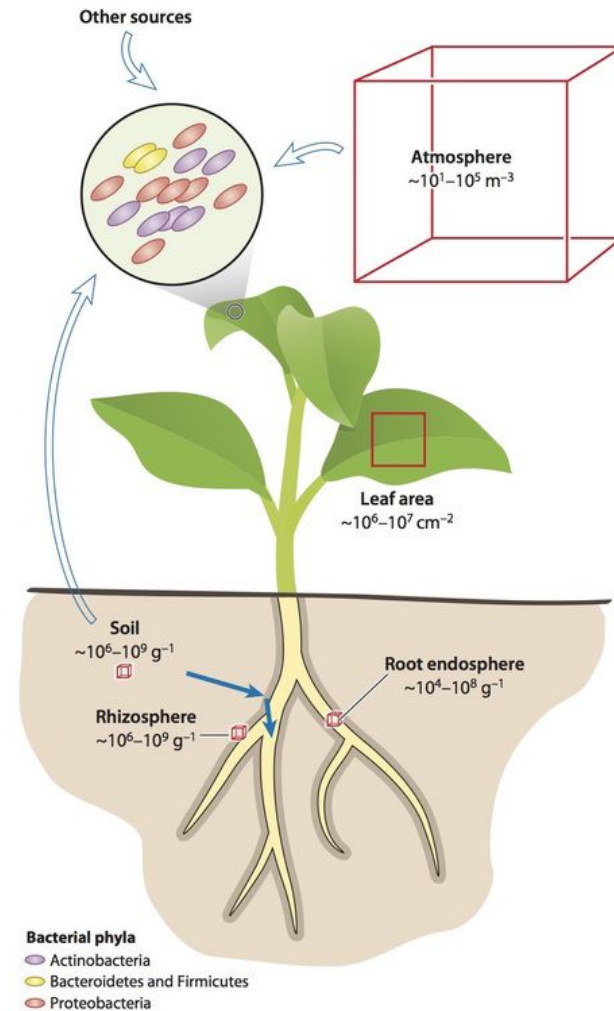
Endosphere

Epiphyte

Endophyte

Endosymbiont (intra-cellular)

Do these numbers match your predictions? Discuss any discrepancies.



# Types of Interactions



Interaction (effect on  
bacteria, effect on  
plant)

Pathogenic (+,-)

Mutualistic (+,+)

Commensal (+,0) or  
(0,+)

Amensal (0,-) or (-,0)





# Bacterial Pathogens

## Bacterial Diseases

*from Agrios, G. N. 2004. Plant Pathology – 5th Edition. Elsevier Academic Press. 922 pp. (ISBN 10 = 0120445654; ISBN-13 = 978-0120445653)*

Bacterial blights of beans

Fire blight

Black rot of cabbage

Bacterial soft rot

Crown gall

Citrus canker

Common scab

Fastidious vascular bacteria

“Plant pathogenic bacteria cause many serious diseases of plants throughout the world (Vidhyasekaran 2002; Figure 2), but fewer than fungi or viruses, and they cause relatively less damage and economic cost (Kennedy and Alcorn 1980).”

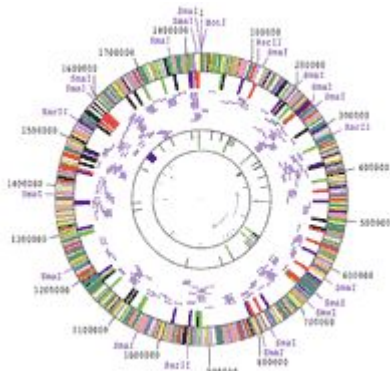
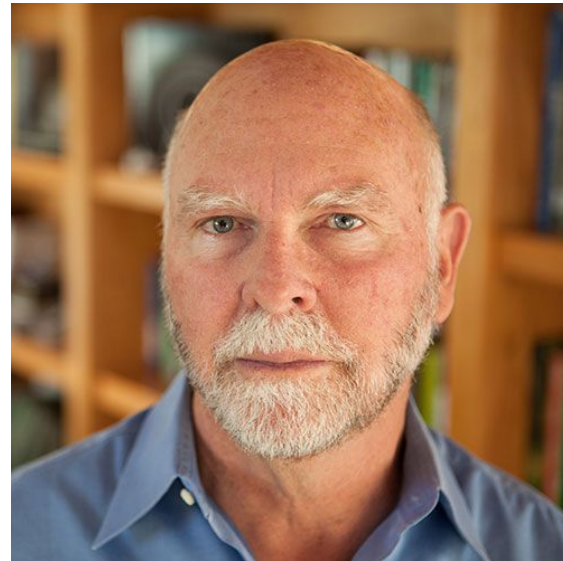
<https://www.apsnet.org/edcenter/intropp/PathogenGroups/Pages/Bacteria.aspx>

# Beneficial Bacteria

1. Nutritional mutualists:
  - a. Nitrogen-fixation
  - b. Phosphate solubilization
2. Protection from pathogens:
  - a. Direct inhibition of pathogens
  - b. Priming of plant immune system
3. Enhanced tolerance of abiotic stress
  - a. Produce osmolytes
  - b. Phytohormone production

(Friesen et al. 2011)

# J. Craig Venter



## RESEARCH ARTICLES

### Whole-genome random sequencing and assembly of *Haemophilus influenzae* Rd

RD Fleischmann, MD Adams, O White, RA Clayton, EF Kirkness, AR Kerlavage, CJ Bult, JF Tomb, BA Dougherty, JM Merrick, et al.

+ See all authors and affiliations

*Science* 28 Jul 1995:  
Vol. 269, Issue 5223, pp. 496-512  
DOI: 10.1126/science.7542800

[http://www.genomenewsnetwork.org/resources/timeline/1995\\_Haemophilus.php](http://www.genomenewsnetwork.org/resources/timeline/1995_Haemophilus.php)

# What is a species?

- Interbreed & share a similar niche
- Morphological features

Ecotype: subpopulation of a species that has distinct ecological characteristics, i.e., expresses phenotypes that are adaptive to a subset of environments [genotype fits the environment]

# The Pan-genome

Pan = All, the union of all branches of a group.

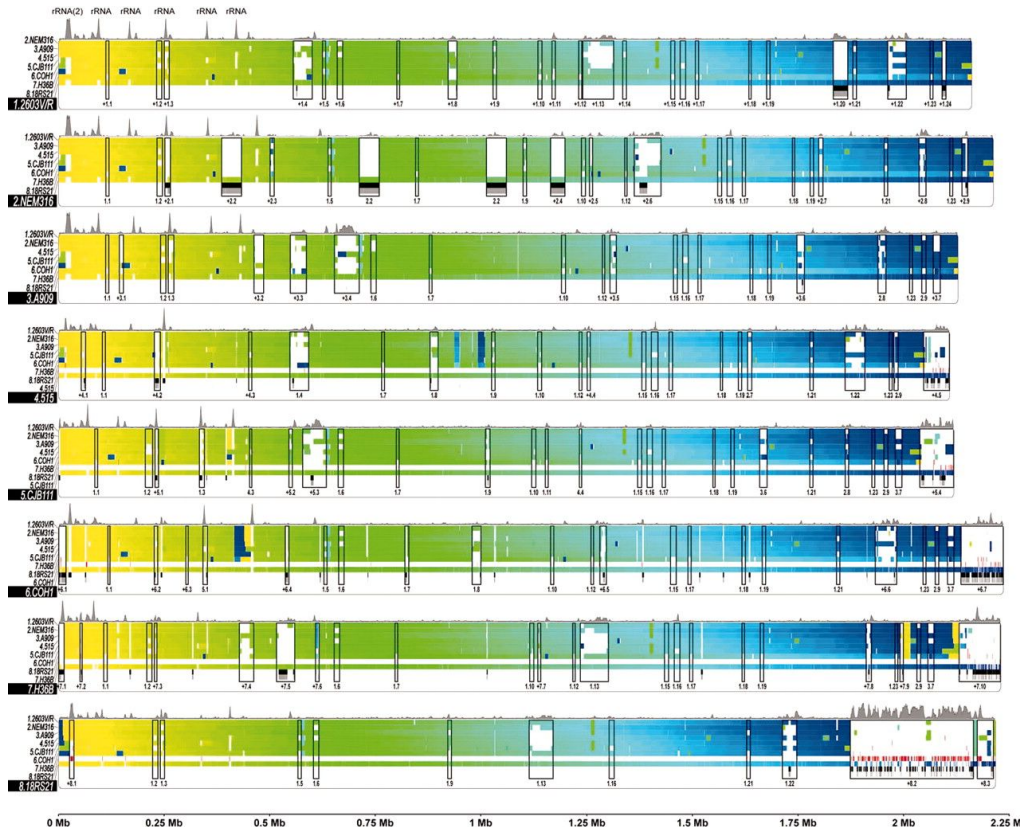
## Genome analysis of multiple pathogenic isolates of *Streptococcus agalactiae*: Implications for the microbial “pan-genome”



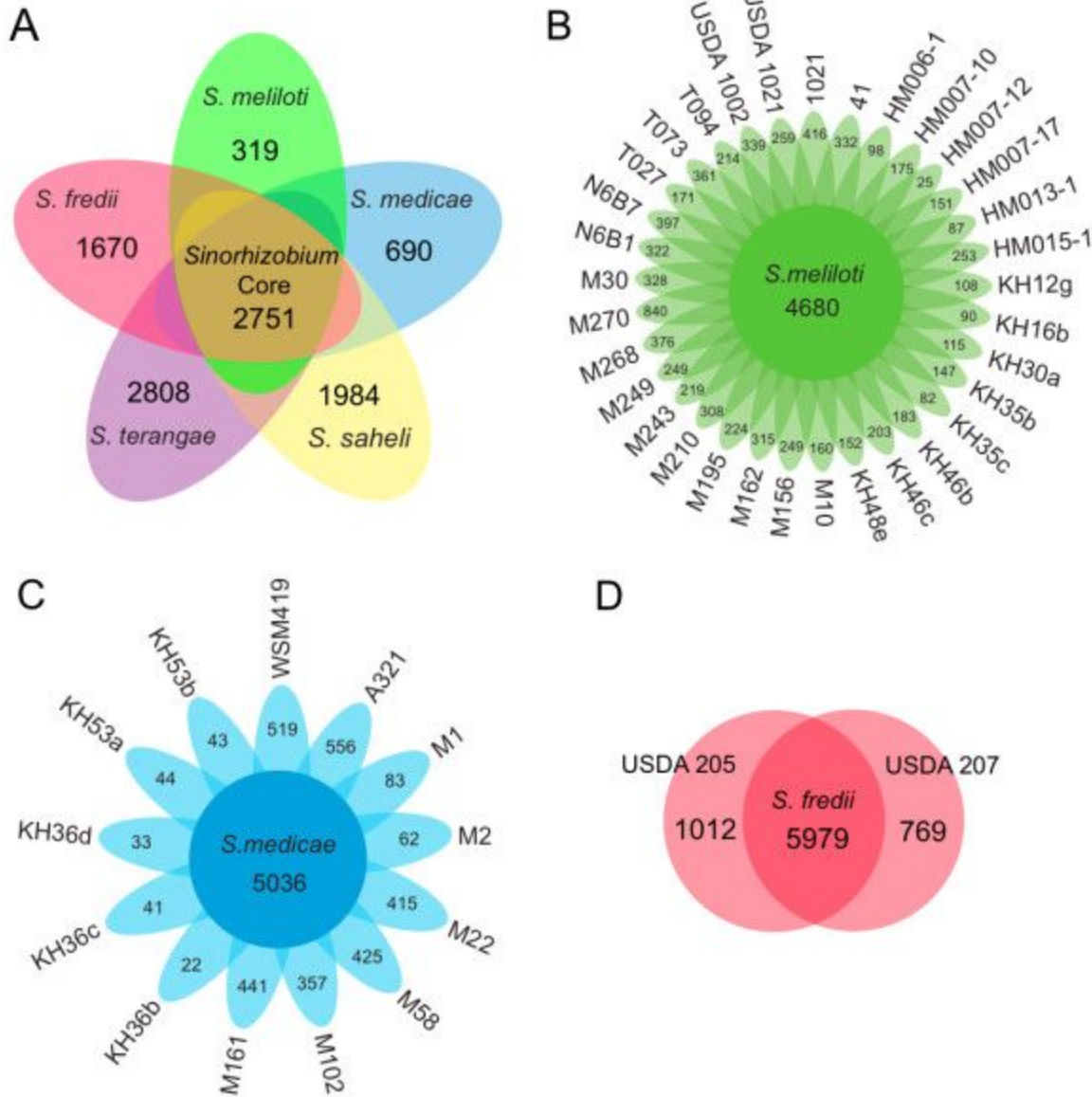
Tettelin et al. 2005

8 strains, only share  
~80% of genes!

Conclude that  
hundreds of genomes  
will not capture  
diversity in this  
species!!







Core genome: found in all (or nearly all)

Accessory / dispensible / flexible genome: found in some strains

Can define at multiple levels (e.g., panel A).

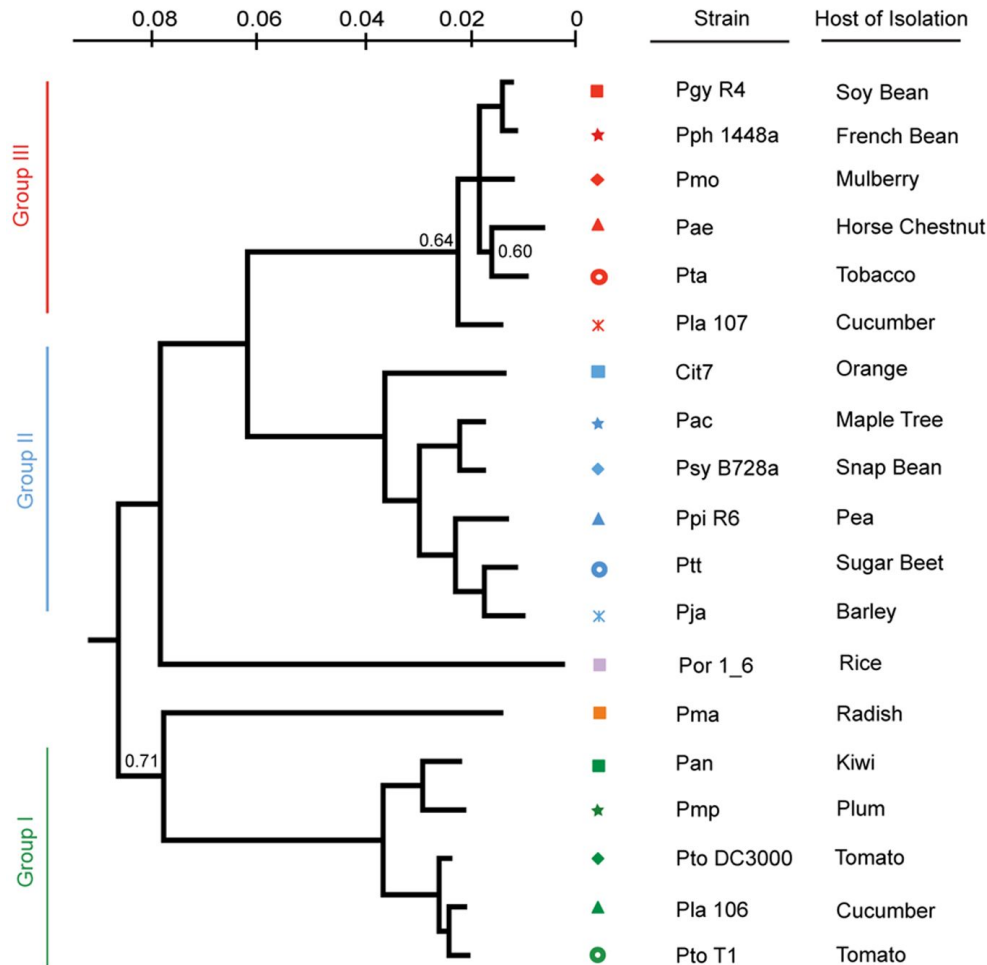
Figure 3. Sugawara et al.

# Dynamic Evolution of Pathogenicity Revealed by Sequencing and Comparative Genomics of 19 *Pseudomonas syringae* Isolates

20

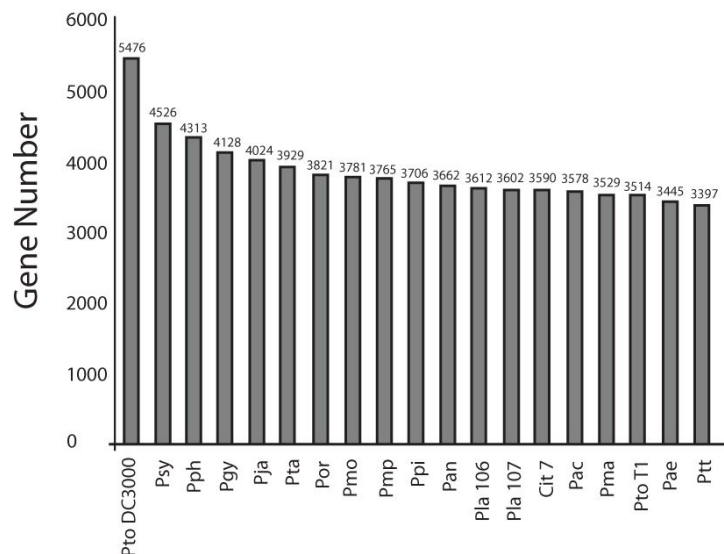
David A. Baltrus , Marc T. Nishimura , Artur Romanchuk, Jeff H. Chang, M. Shahid Mukhtar, Karen Cherkis, Jeff Roach, Sarah R. Grant, Corbin D. Jones , Jeffery L. Dangl 

Published: July 14, 2011 • <https://doi.org/10.1371/journal.ppat.1002132>

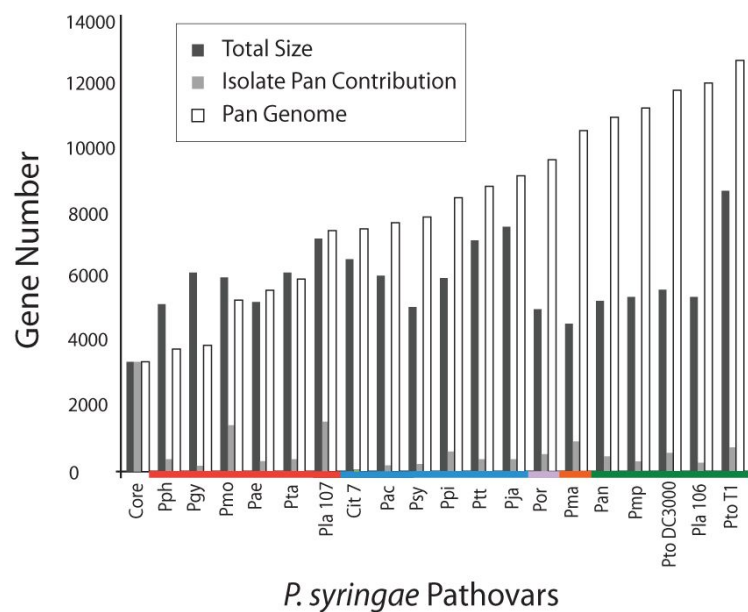


Phylogenetic analysis of the 19 strains included in this study based on nucleotide sequence of seven conserved loci. Bayesian posterior probabilities are displayed on the phylogeny only at nodes where these values are <0.95. For these unresolved nodes, we used an independent phylogenetic approach on another 324 genes that confirmed that this tree captures the evolutionary history of these nodes

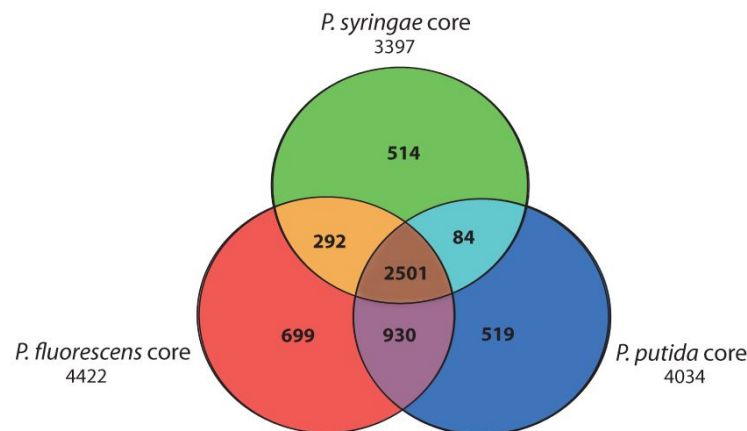
A



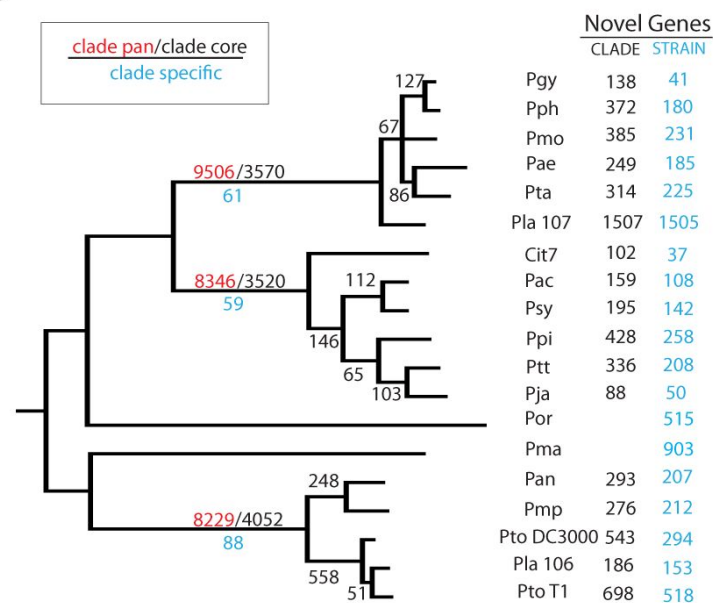
B



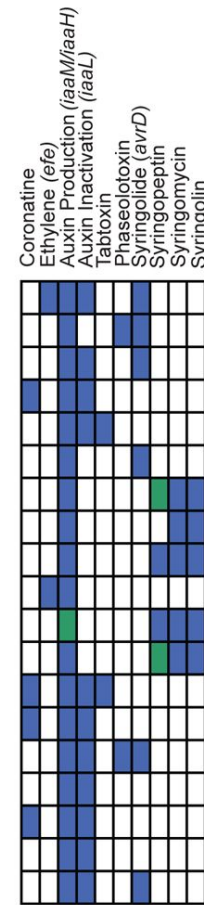
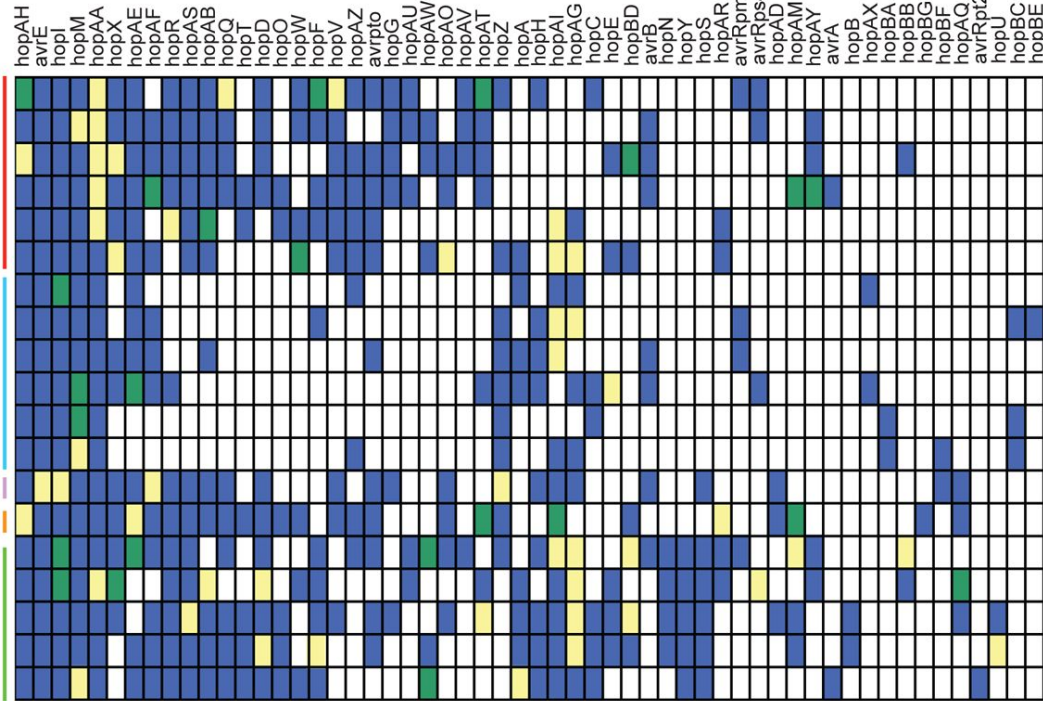
C



D

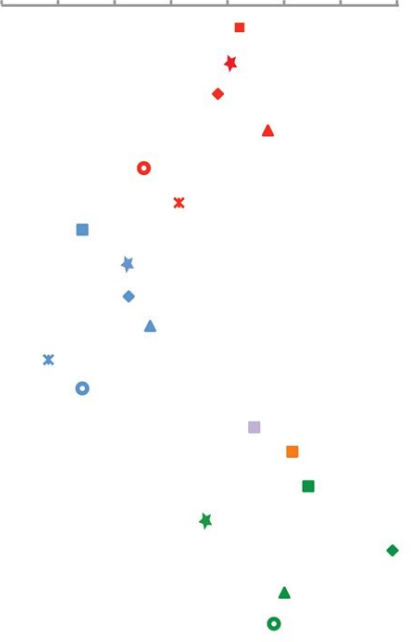


ORF Present
  ORF Present, Unconfirmed
  ORF Disrupted or Truncated
  ORF Absent



Number of Potential Full Length Effectors Per Strain

5 10 15 20 25 30 35 40



Chrome: Secure Shell (extension; runs command line in your browser! How cool is that?)

Friesen, White, Porter - PLP512 - 2019-08-27 Intro



# Command line - Intro (Unix)

Open a terminal

Type `pwd`

-> tell me where your are?

Type `ls`

-> tell me what you see?

Type `touch file.txt`

Type `ls`

-> what happened?

# Command line - Intro (Unix)

cd - Change directory

pwd - your full path of directory

mkdir - make a new directory

rm - remove a file

head - first 5 lines of a file

tail - last 5 lines of a file

more - scroll file top to bottom

| - what is this symbol in unix?

mv - move a folder/file or rename?

touch - create a file

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# Command line - Intro (Unix)

More of a detailed introduction listed here:

<https://github.com/raw937/bacterialpopulationgenomics/tree/master/doc>

PLEASE EMAIL ASAP KAMIAK TO GET AN ACCOUNT

You use your wsu email and password as login.

- `kamiak.support@wsu.edu`.

# Command line - Homework

- I will post a command line survey to see what you know
- It will also help me cover material needed to get you ready for next week assembly lecture