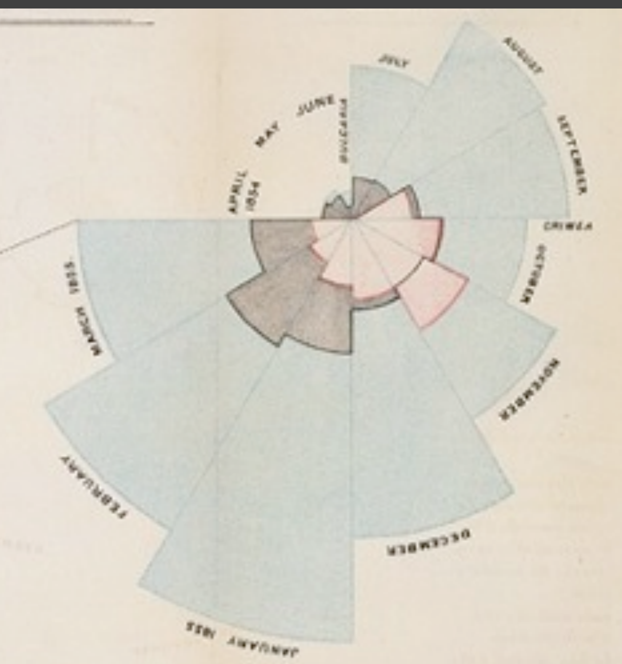
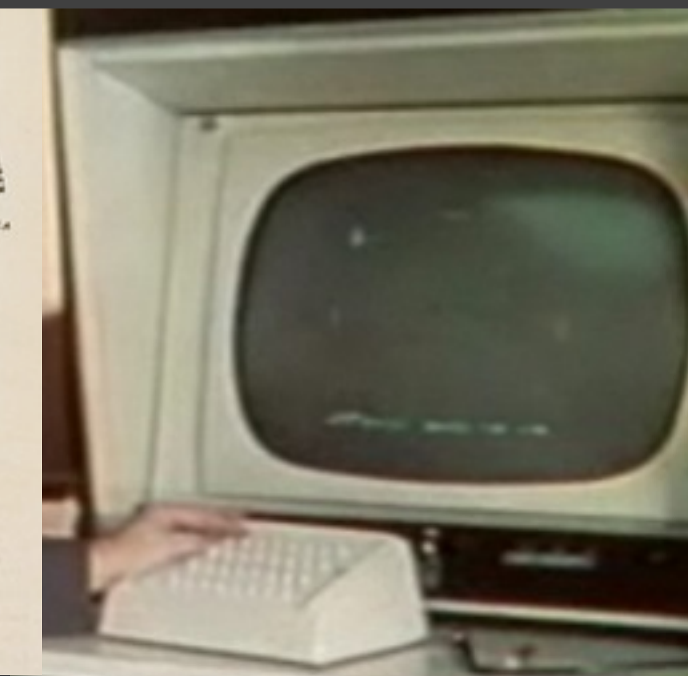
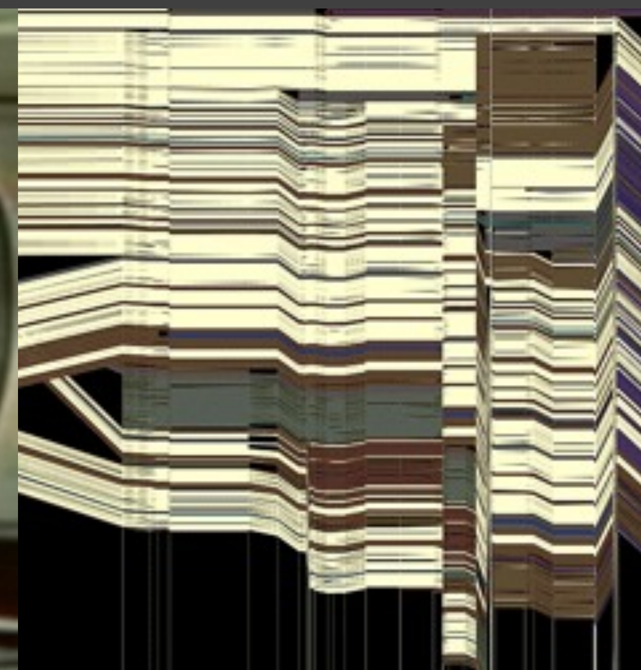
MTI193102 :: 07 Nov 2020

Visualization Design







Joko Triloka

IIB Darmajaya

Last Time:
Data and Image Models

The Big Picture

task

questions & hypotheses
intended audience

data

physical type
- int, float, etc.

abstract type
- nominal, ordinal, etc.

domain

metadata
semantics
conceptual model

processing algorithms

mapping

visual encoding
visual metaphor

→

image

visual channel
perception

Nominal, Ordinal and Quantitative

N - Nominal (labels)

- Operations: =, ≠

O - Ordered (rank-ordered, sorted)

- Operations: =, ≠, <, >

Q - Interval (location of zero arbitrary)

- Operations: =, ≠, <, >, -
- Can measure distances or spans

Q - Ratio (zero fixed)

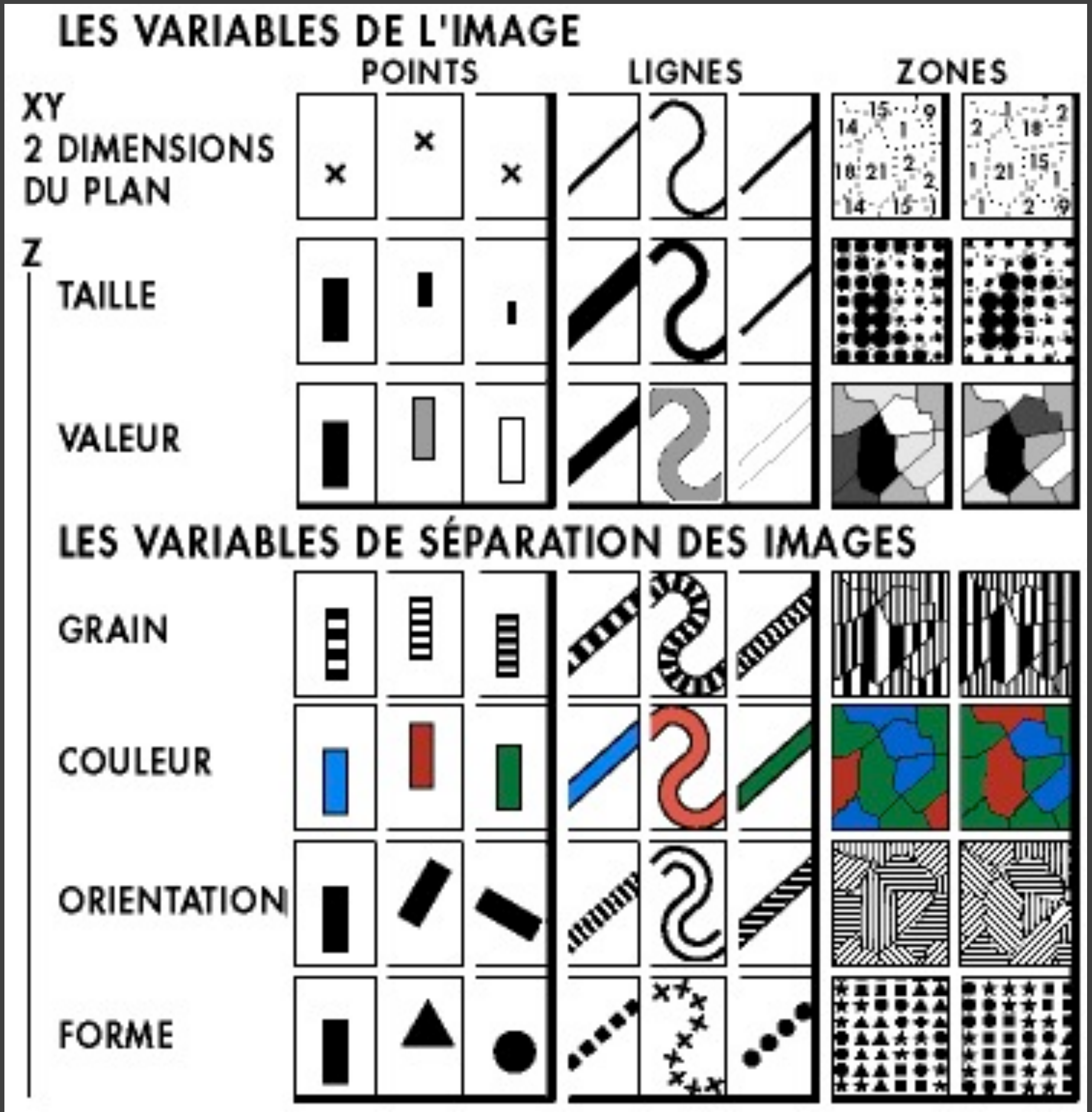
- Operations: =, ≠, <, >, -, %
- Can measure ratios or proportions

S. S. Stevens, On the theory of scales of measurements, 1946

Visual Encoding Variables

Position
Size
Value
Texture
Color
Orientation
Shape

Others?



Formalizing Design

(Mackinlay 1986)

Choosing Visual Encodings

Challenge:
Assume 8 visual encodings and *n* data attributes.
We would like to pick the “best” encoding among a combinatorial set of possibilities with size $(n+1)^8$

Principle of Consistency:
The properties of the image (visual variables) should match the properties of the data.

Principle of Importance Ordering:
Encode the most important information in the most effective way.

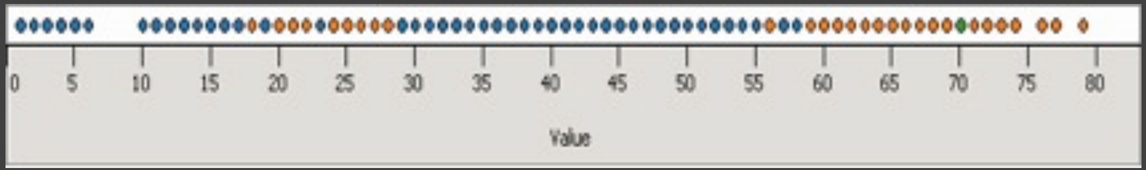
Design Criteria (Mackinlay)

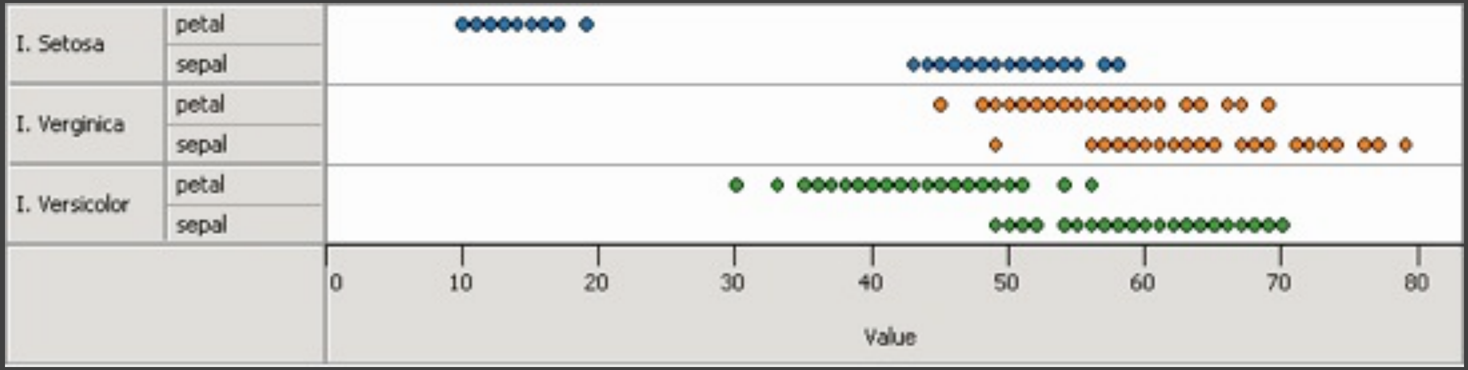
Expressiveness

A set of facts is expressible in a visual language if the sentences (i.e. the visualizations) in the language express all the facts in the set of data, and only the facts in the data.

Cannot express the facts

A one-to-many (1 → N) relation cannot be expressed in a single horizontal dot plot because multiple tuples are mapped to the same position





Expresses facts not in the data

A length is interpreted as a quantitative value;
∴ Length of bar says something untrue about N data

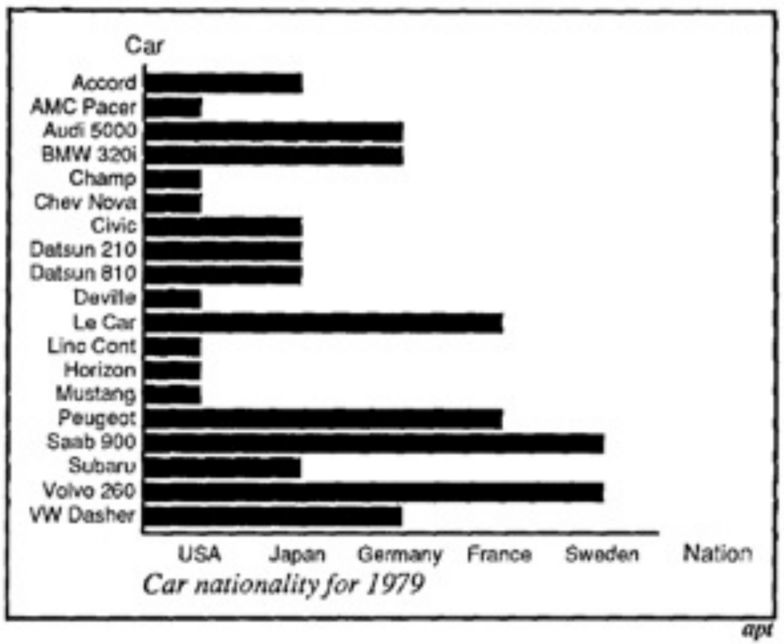


Fig. 11. Incorrect use of a bar chart for the *Nation* relation. The lengths of the bars suggest an ordering on the vertical axis, as if the USA cars were longer or better than the other cars, which is not true for the *Nation* relation.

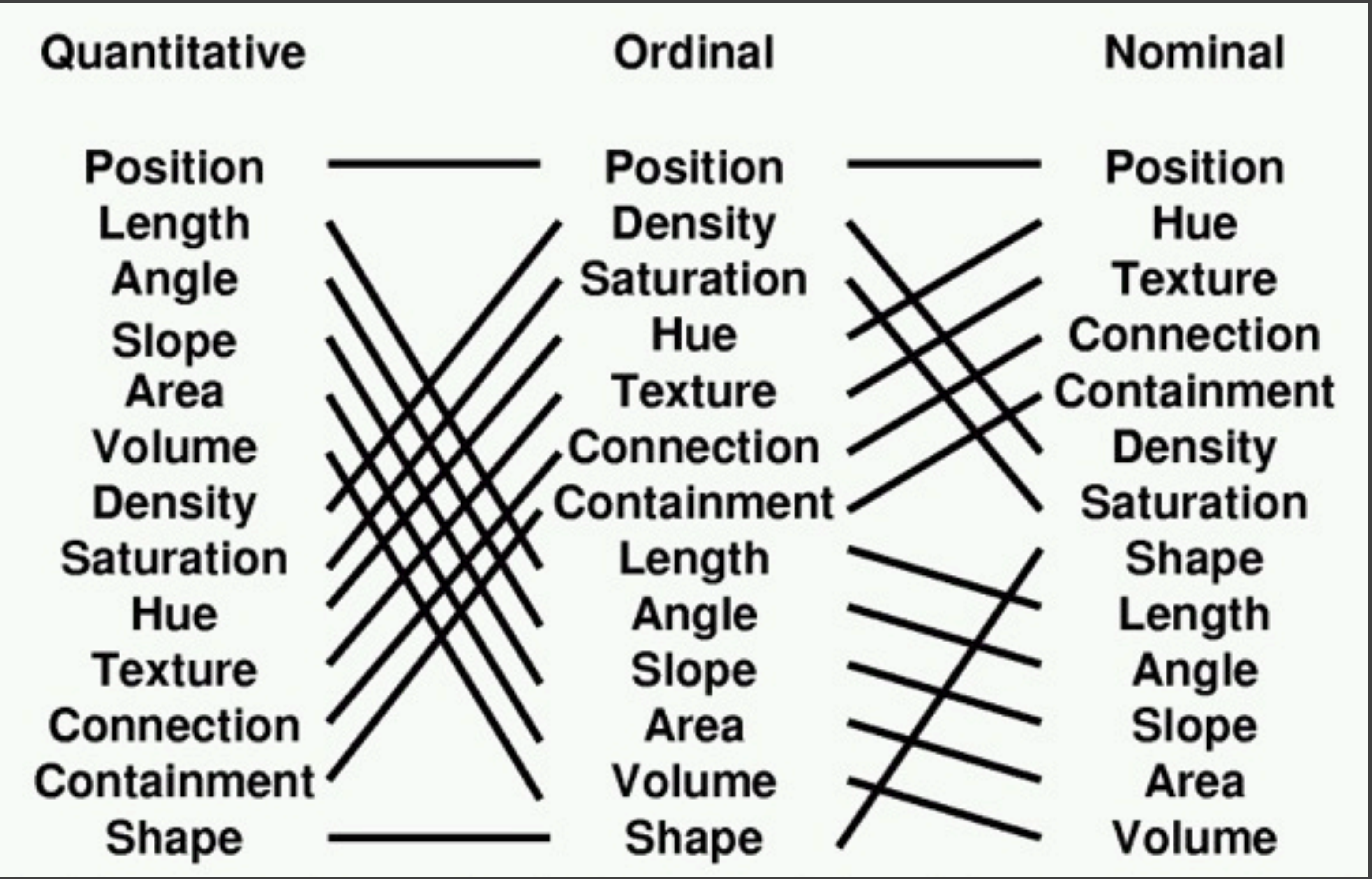
[Mackinlay, APT, 1986]

Design Criteria (Mackinlay)

Expressiveness
A set of facts is expressible in a visual language if the sentences (i.e. the visualizations) in the language express all the facts in the set of data, and only the facts in the data.

Effectiveness
A visualization is more effective than another visualization if the information conveyed by one visualization is more readily perceived than the information in the other visualization.

Mackinlay's Ranking



Conjectured *effectiveness* of the encoding

Mackinlay's Design Algorithm

User formally specifies data model and type

- Additional input: ordered list of data variables to show

APT searches over design space

- Tests expressiveness of each visual encoding
- Generates specification for encodings that pass test
- Tests perceptual effectiveness of resulting image

Outputs the "most effective" visualization

Limitations

Does not cover many visualization techniques

- Bertin and others discuss networks, maps, diagrams
- Does not consider 3D, animation, illustration, photography, …

Does not model interaction

Does not consider semantic data types / conventions

Design Considerations

Title, labels, legend, captions, source!

Expressiveness and Effectiveness

Avoid unexpressive marks (lines? bars? gradients?)

Use perceptually effective encodings

Don't distract: faint gridlines, pastel highlights/fills

The "elimination diet" approach – start minimal

Support comparison and pattern perception

Between elements, to a reference line, or to totals

Design Considerations

Group / sort data by meaningful dimensions

Transform data (e.g., invert, log, normalize)

Are model choices (regression lines) appropriate?

Reduce cognitive overhead

Minimize visual search, minimize ambiguity

-> Avoid legend lookups if direct labeling works

-> Avoid color mappings with indiscernible colors

Be consistent! **Visual inferences** should consistently support **data inferences**

In-Class Review Rubric

Expressiveness

- Prioritizes important information / Avoids false inferences
- Consistent visual mappings (e.g., respect color mappings)
- Make encodings *meaningful* rather than arbitrary

Effectiveness

- Facilitates accurate decoding / Minimizes cognitive overhead
- Highlight elements of primary interest

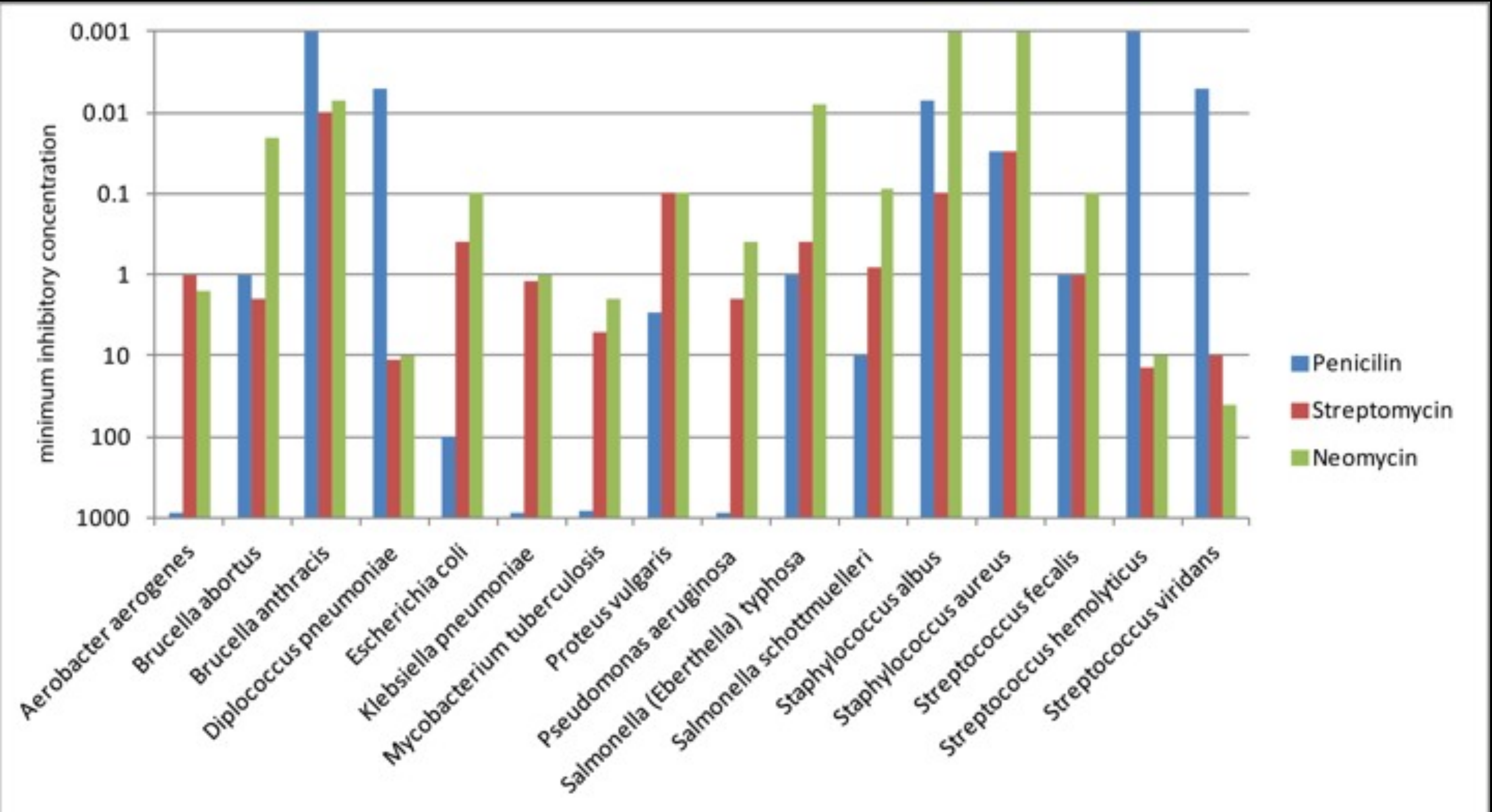
Grouping / Sorting

Data Transformation

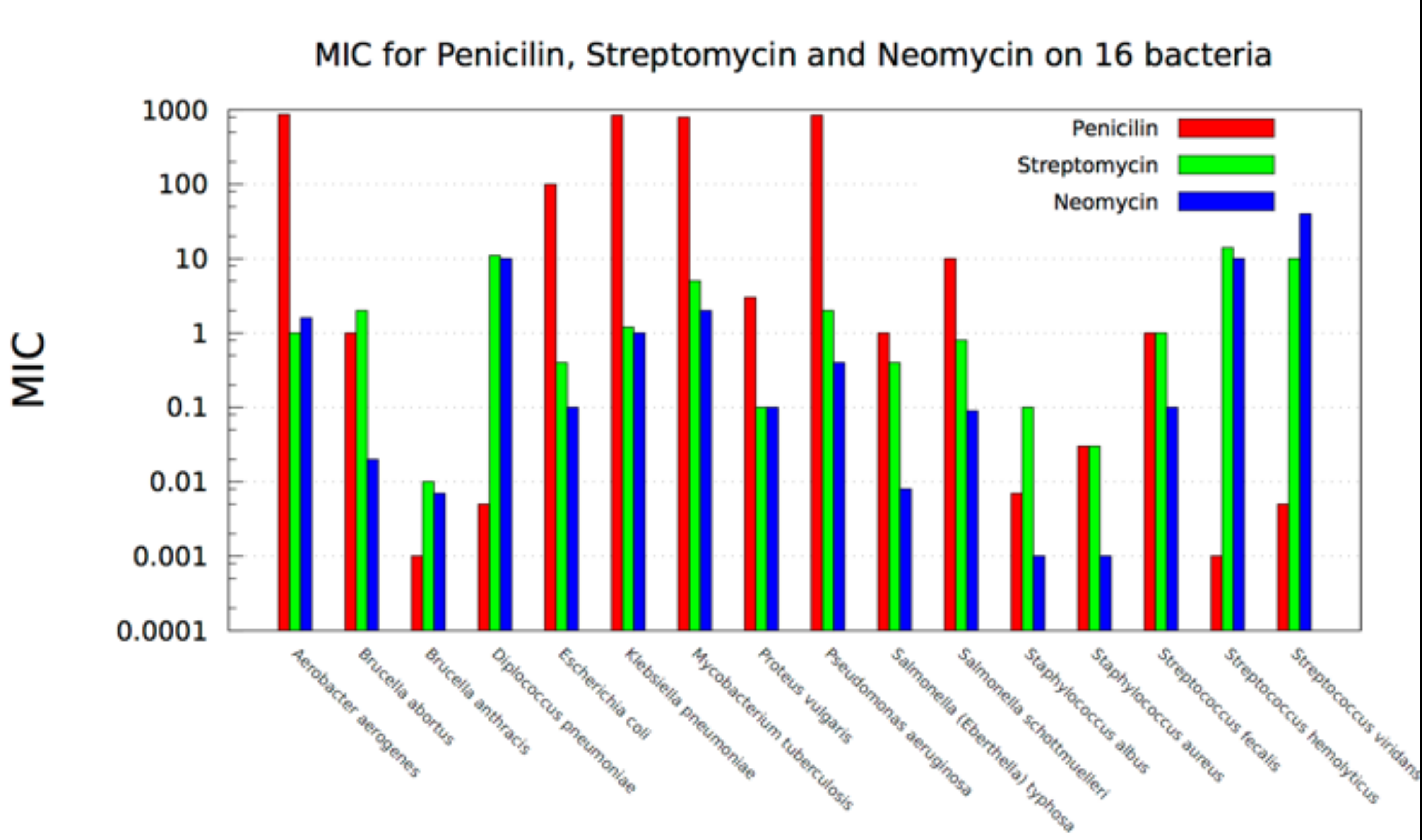
Non-Data Elements

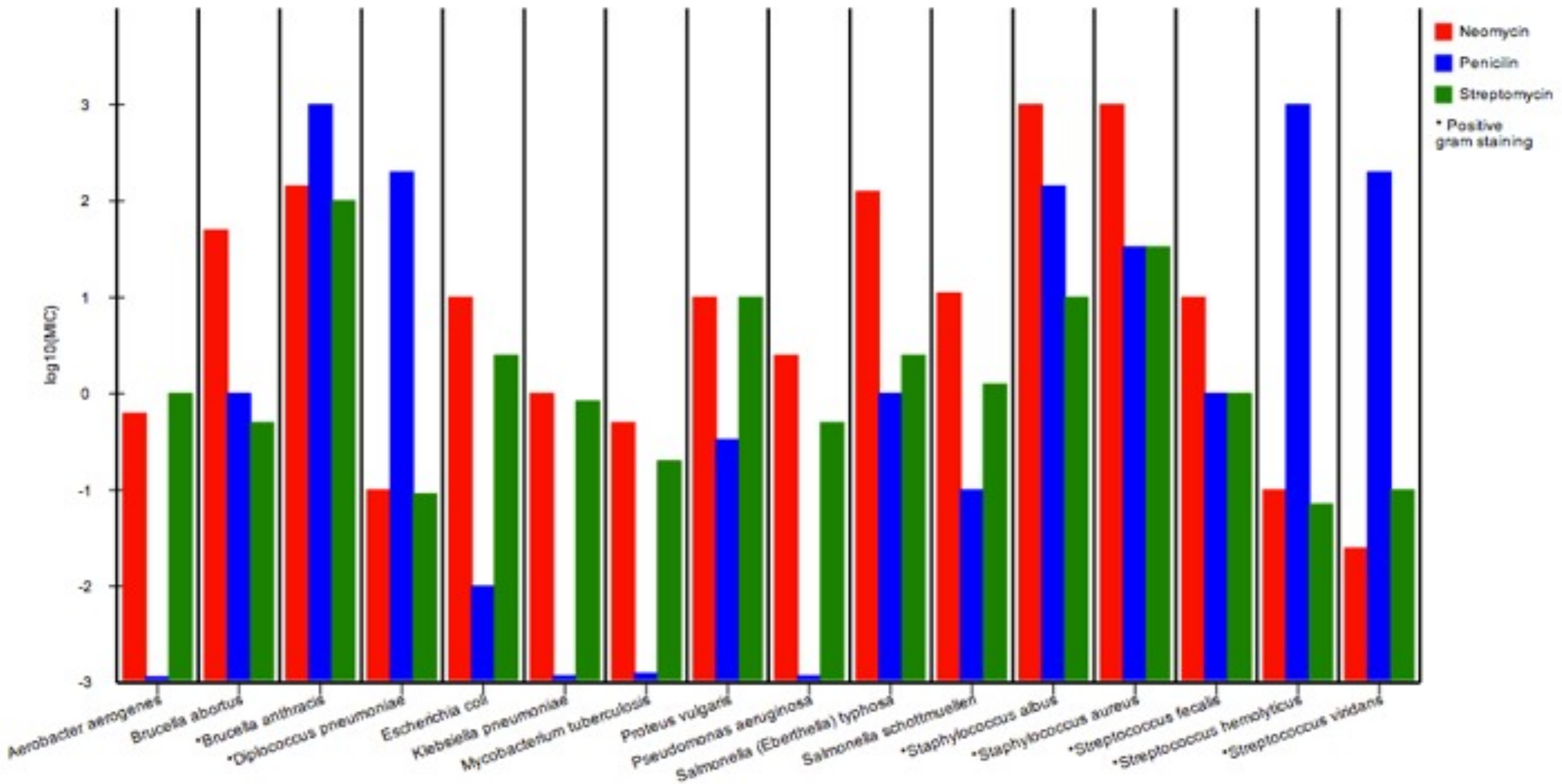
- Descriptive: Title, Label, Caption, Data Source, Annotations
- Reference: Gridlines, Legend

Bar Charts



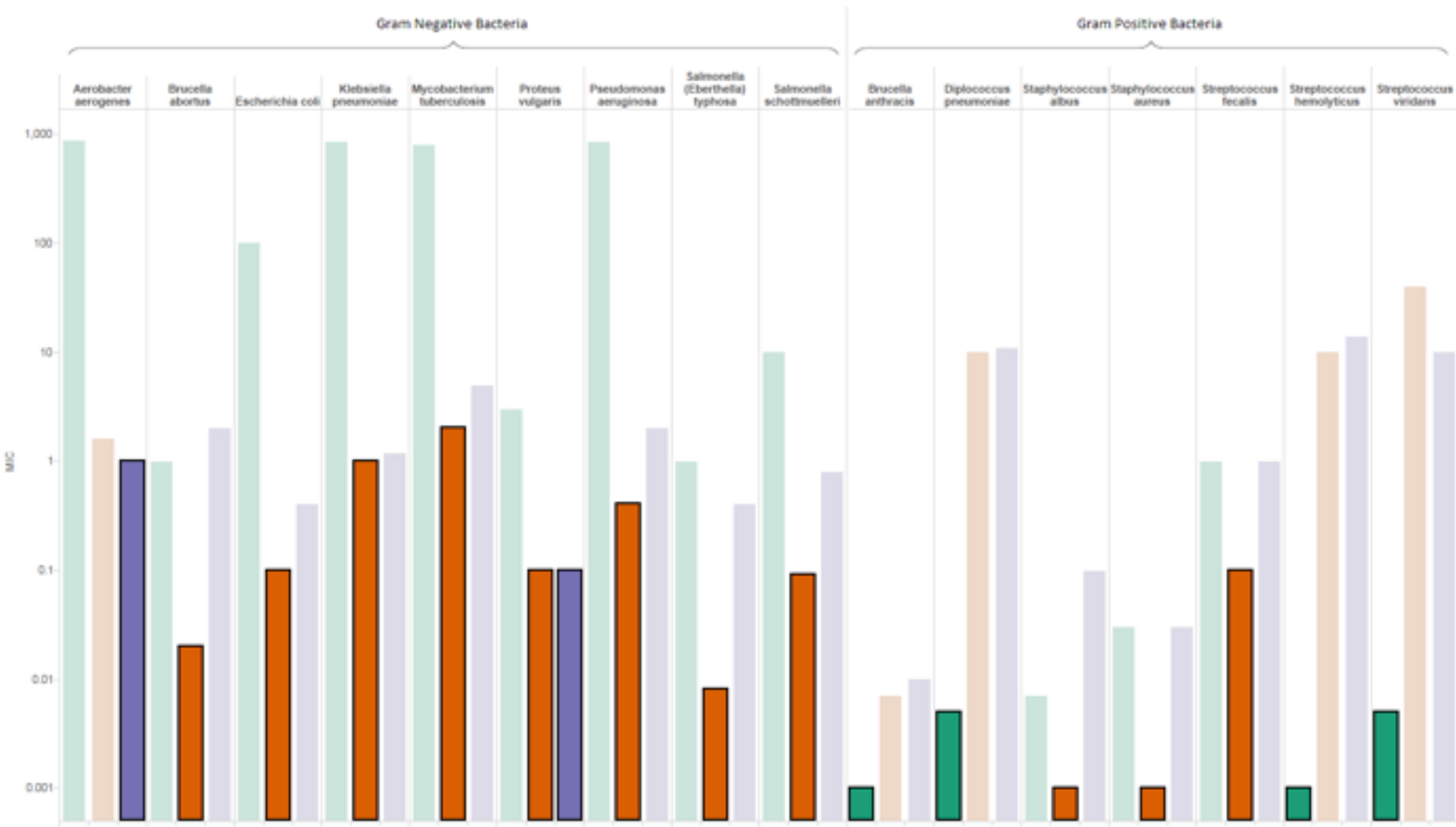
minimum inhibitory concentration
0.001
0.01
0.1
1
10
100
1000
Aerobacter aerogenes
Brucella abortus
Brucella anthracis
Diplococcus pneumoniae
Escherichia coli
Klebsiella pneumoniae
Mycobacterium tuberculosis
Proteus vulgaris
Pseudomonas aeruginosa
Salmonella (Eberthella) typhosa
Salmonella schottmuelleri
Staphylococcus albus
Staphylococcus aureus
Streptococcus fecalis
Streptococcus hemolyticus
Streptococcus viridans
Penicilin
Streptomycin
Neomycin


MIC for Penicilin, Streptomycin and Neomycin on 16 bacteria
MIC
1000
100
10
1
0.1
0.01
0.001
0.0001
Penicilin
Streptomycin
Neomycin
Aerobacter aerogenes
Brucella abortus
Brucella anthracis
Diplococcus pneumoniae
Escherichia coli
Klebsiella pneumoniae
Mycobacterium tuberculosis
Proteus vulgaris
Pseudomonas aeruginosa
Salmonella (Eberthella) typhosa
Salmonella schottmuelleri
Staphylococcus albus
Staphylococcus aureus
Streptococcus fecalis
Streptococcus hemolyticus
Streptococcus viridans

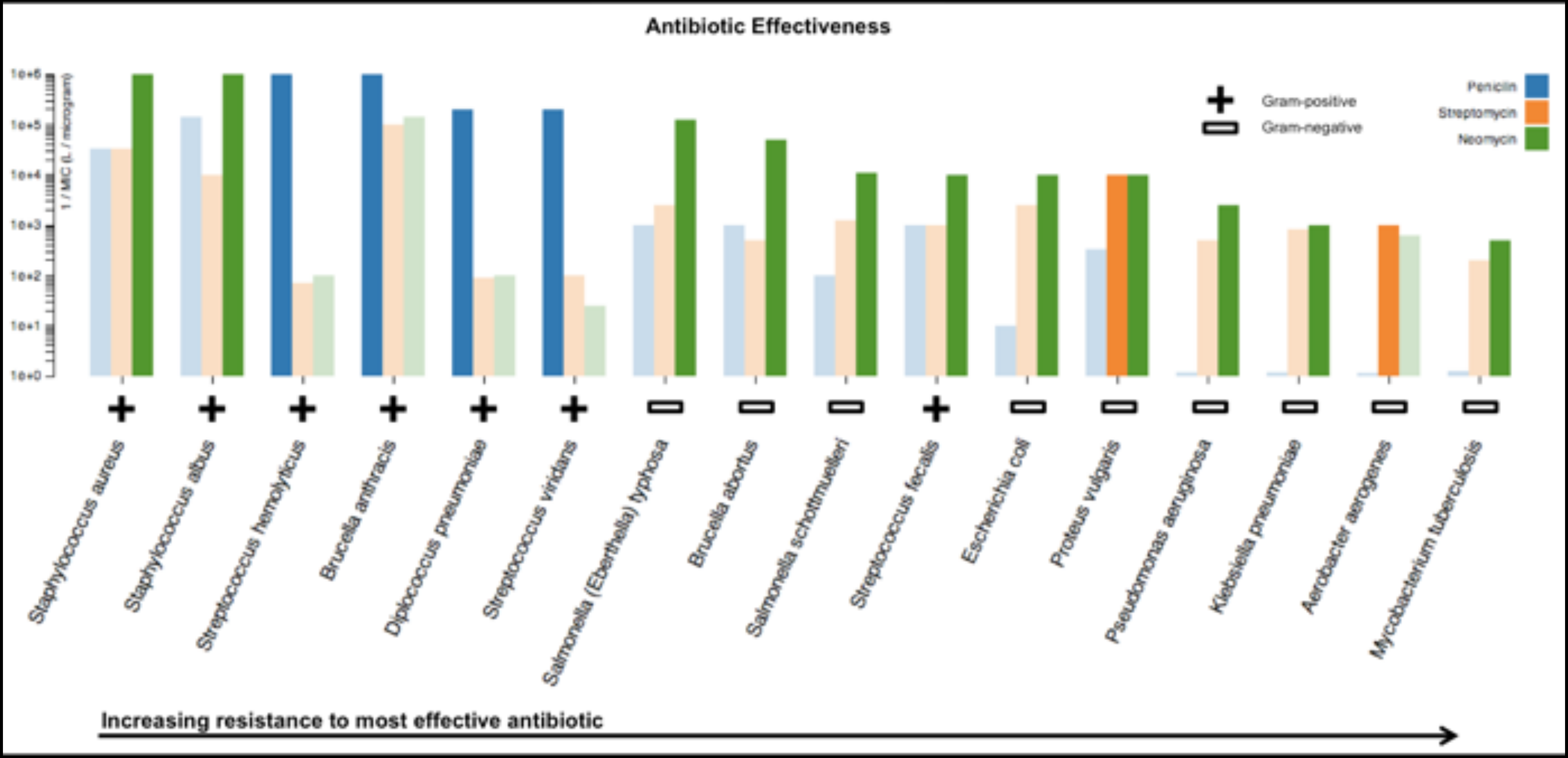


log10(MIC)
3
2
1
0
-1
-2
-3
Neomycin
Penicilin
Streptomycin
* Positive gram staining
Aerobacter aerogenes
Brucella abortus
*Brucella anthracis
*Diplococcus pneumoniae
Escherichia coli
Klebsiella pneumoniae
Mycobacterium tuberculosis
Proteus vulgaris
Pseudomonas aeruginosa
Salmonella (Eberthella) typhosa
Salmonella schottmuelleri
*Staphylococcus albus
*Staphylococcus aureus
*Streptococcus fecalis
*Streptococcus hemolyticus
*Streptococcus viridans

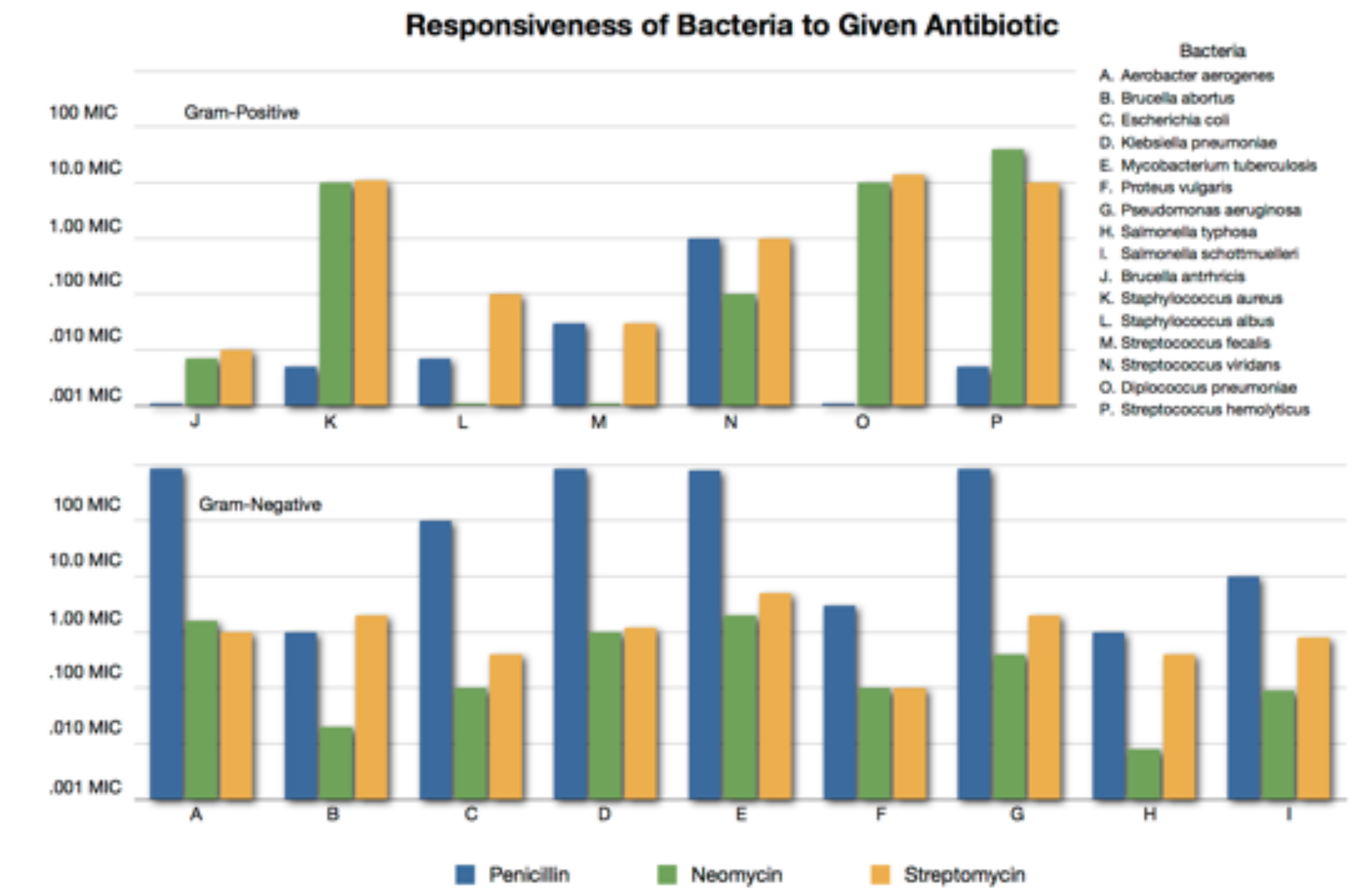
Efficacy of Penicillin (■), Neomycin (■) and Streptomycin (■) against various bacteria



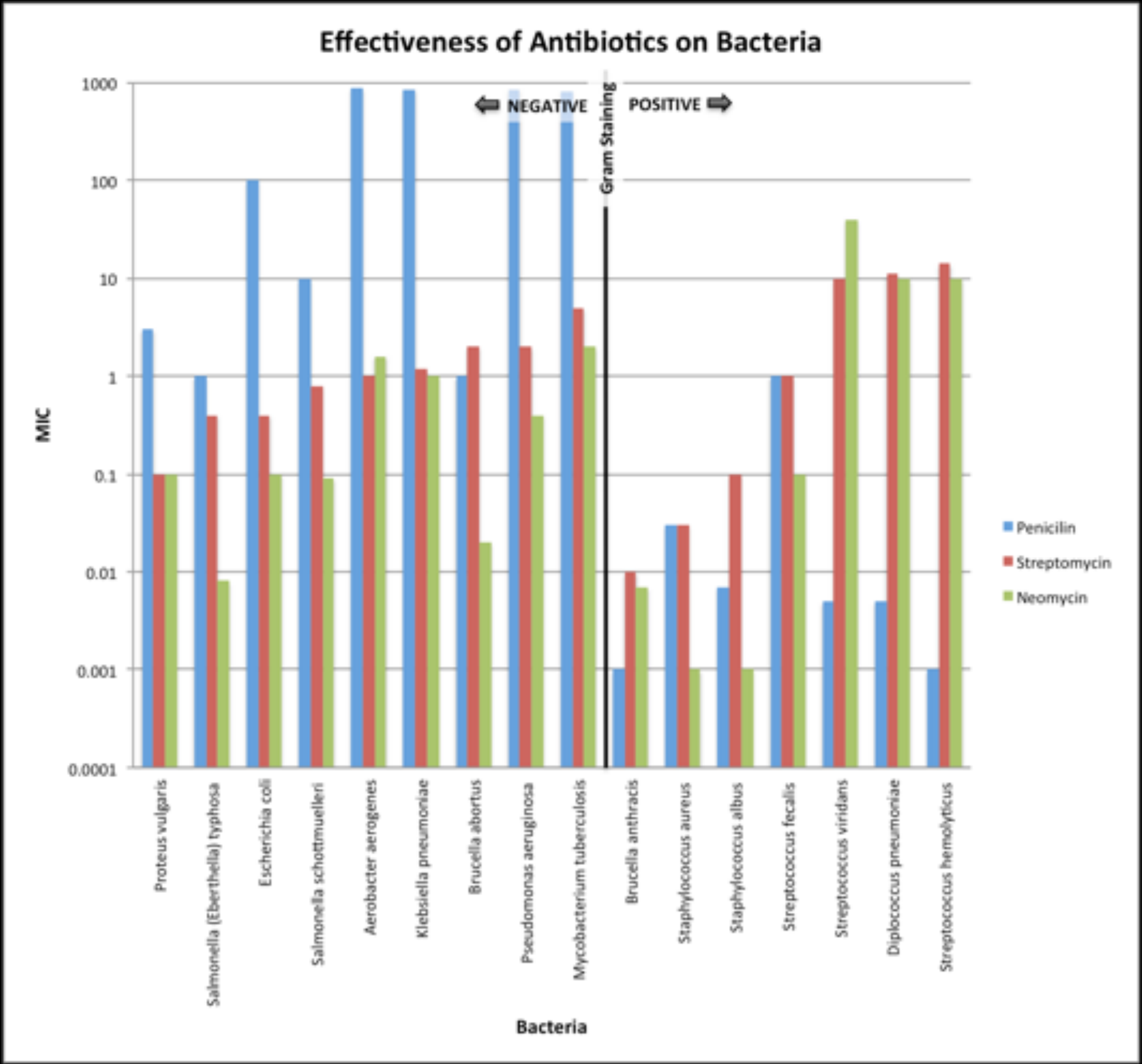
MICs (note log scale) of Penicillin, Neomycin and Streptomycin are shown for various strains of bacteria. Most effective antibiotic is highlighted for each bacterium.

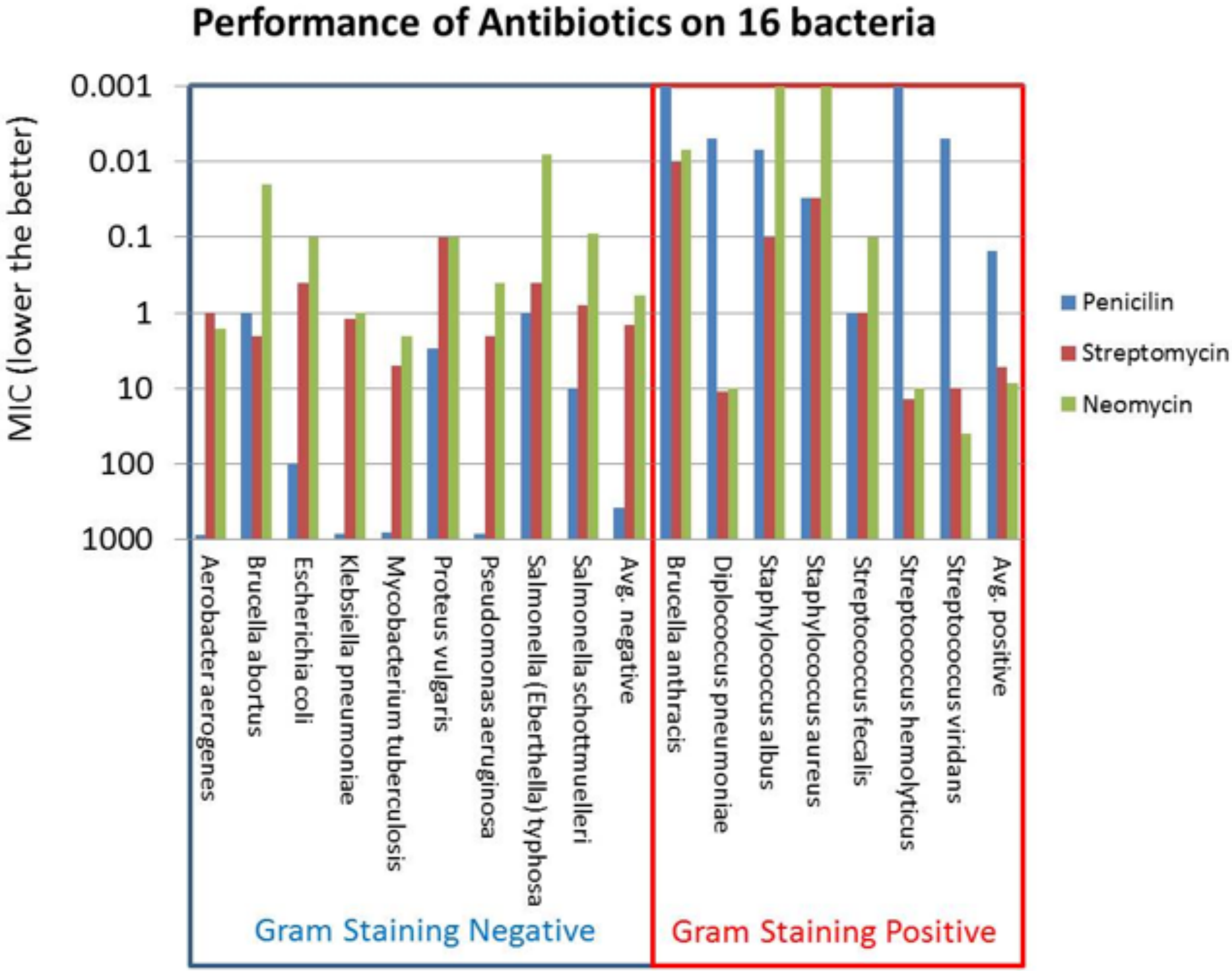


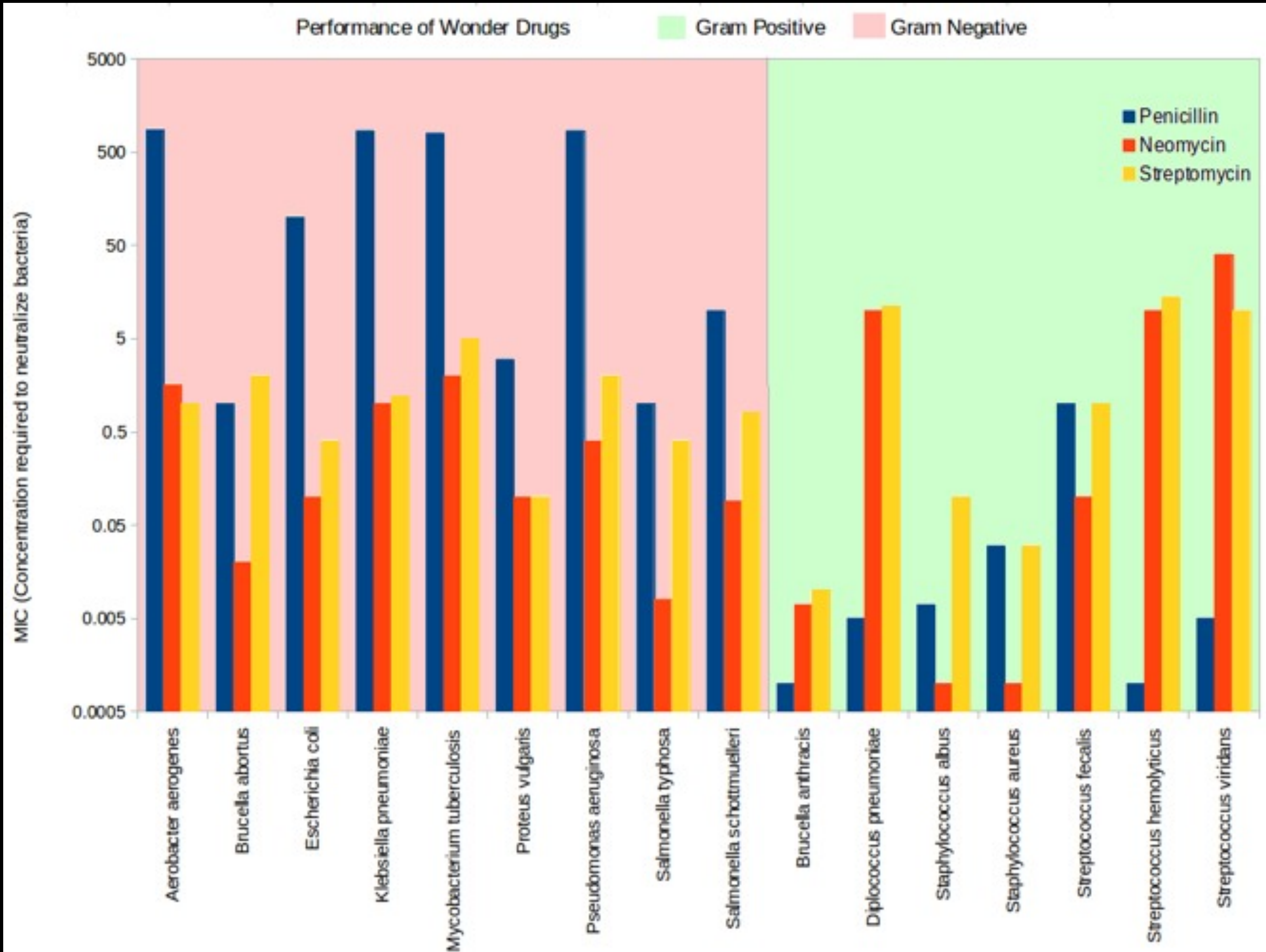
Antibiotic Effectiveness
1 / MIC (L / microgram)
1e+6
1e+5
1e+4
1e+3
1e+2
1e+1
1e+0
Gram-positive
Gram-negative
Penicilin
Streptomycin
Neomycin
Staphylococcus aureus
Staphylococcus albus
Streptococcus hemolyticus
Brucella anthracis
Diplococcus pneumoniae
Streptococcus viridans
Salmonella (Eberthella) typhosa
Brucella abortus
Salmonella schottmuelleri
Streptococcus fecalis
Escherichia coli
Proteus vulgaris
Pseudomonas aeruginosa
Klebsiella pneumoniae
Aerobacter aerogenes
Mycobacterium tuberculosis
Increasing resistance to most effective antibiotic



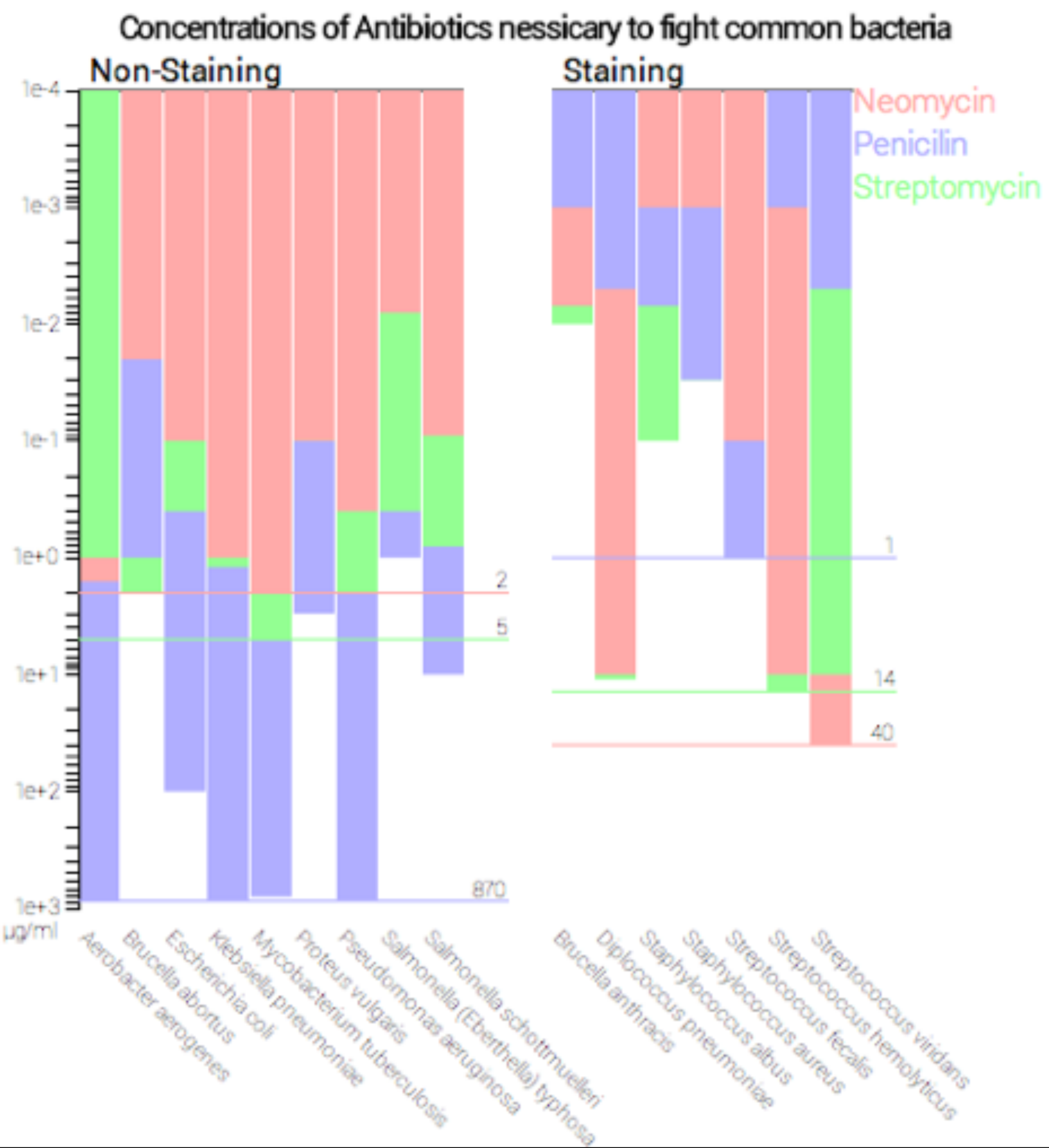
Responsiveness of Bacteria to Given Antibiotic
Gram-Positive
100 MIC
10.0 MIC
1.00 MIC
.100 MIC
.010 MIC
.001 MIC
J
K
L
M
N
O
P
Bacteria
A. Aerobacter aerogenes
B. Brucella abortus
C. Escherichia coli
D. Klebsiella pneumoniae
E. Mycobacterium tuberculosis
F. Proteus vulgaris
G. Pseudomonas aeruginosa
H. Salmonella typhosa
I. Salmonella schottmuelleri
J. Brucella antrhricis
K. Staphylococcus aureus
L. Staphylococcus albus
M. Streptococcus fecalis
N. Streptococcus viridans
O. Diplococcus pneumoniae
P. Streptococcus hemolyticus
Gram-Negative
100 MIC
10.0 MIC
1.00 MIC
.100 MIC
.010 MIC
.001 MIC
A
B
C
D
E
F
G
H
I
Penicillin
Neomycin
Streptomycin

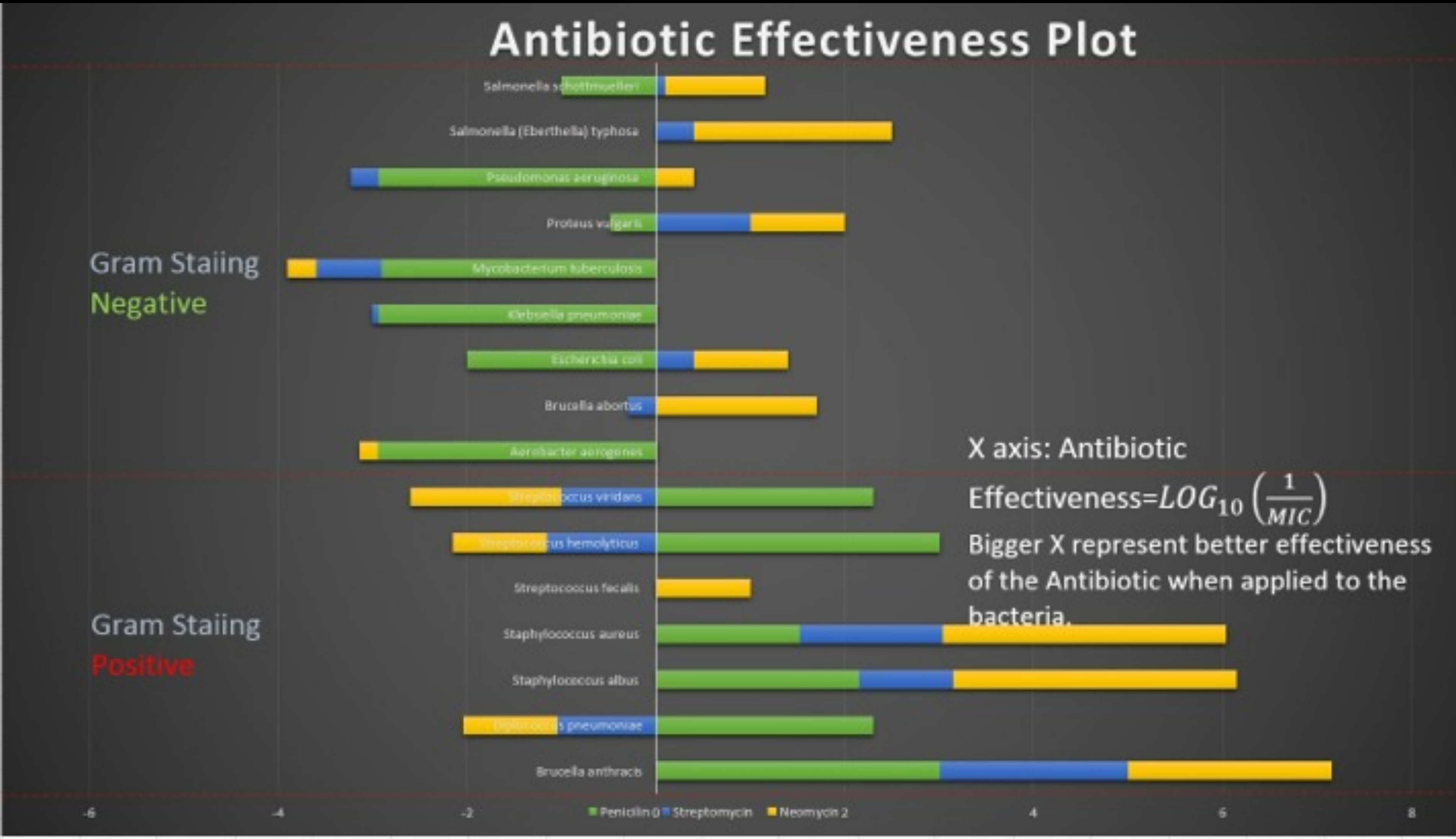

Effectiveness of Antibiotics on Bacteria
NEGATIVE
Gram Staining
POSITIVE
MIC
1000
100
10
1
0.1
0.01
0.001
0.0001
Proteus vulgaris
Salmonella (Eberthella) typhosa
Escherichia coli
Salmonella schottmuelleri
Aerobacter aerogenes
Klebsiella pneumoniae
Brucella abortus
Pseudomonas aeruginosa
Mycobacterium tuberculosis
Brucella anthracis
Staphylococcus aureus
Staphylococcus albus
Streptococcus fecalis
Streptococcus viridans
Diplococcus pneumoniae
Streptococcus hemolyticus
Bacteria
Penicilin
Streptomycin
Neomycin

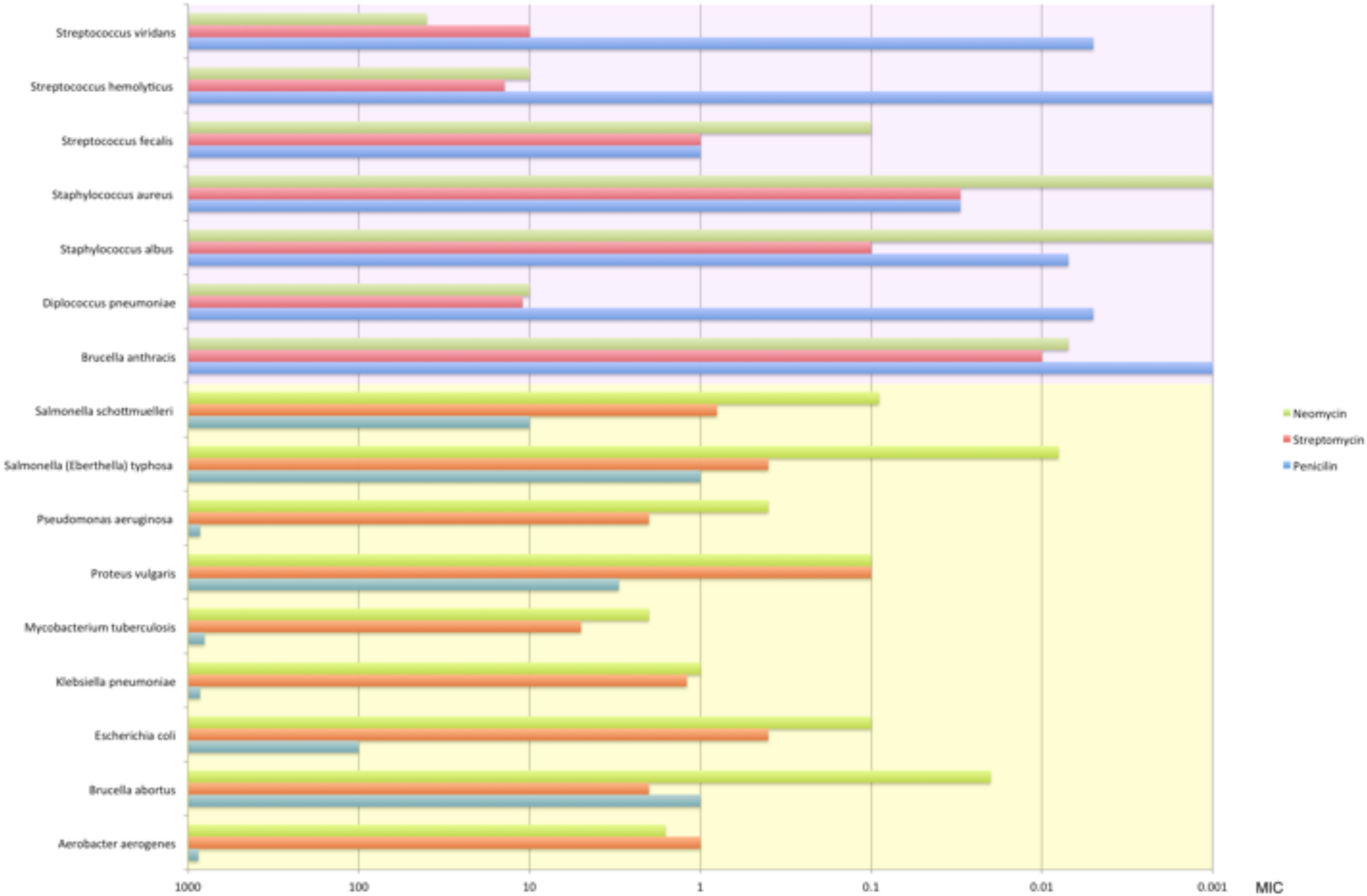

Performance of Antibiotics on 16 bacteria
MIC (lower the better)
0.001
0.01
0.1
1
10
100
1000
Aerobacter aerogenes
Brucella abortus
Escherichia coli
Klebsiella pneumoniae
Mycobacterium tuberculosis
Proteus vulgaris
Pseudomonas aeruginosa
Salmonella (Eberthella) typhosa
Salmonella schottmuelleri
Avg. negative
Brucella anthracis
Diplococcus pneumoniae
Staphylococcus albus
Staphylococcus aureus
Streptococcus fecalis
Streptococcus hemolyticus
Streptococcus viridans
Avg. positive
Gram Staining Negative
Gram Staining Positive
Penicilin
Streptomycin
Neomycin



Performance of Wonder Drugs
Gram Positive
Gram Negative
Penicillin
Neomycin
Streptomycin
MIC (Concentration required to neutralize bacteria)
5000
500
50
5
0.5
0.05
0.005
0.0005
Aerobacter aerogenes
Brucella abortus
Escherichia coli
Klebsiella pneumoniae
Mycobacterium tuberculosis
Proteus vulgaris
Pseudomonas aeruginosa
Salmonella typhosa
Salmonella schottmuelleri
Brucella anthracis
Diplococcus pneumoniae
Staphylococcus albus
Staphylococcus aureus
Streptococcus fecalis
Streptococcus hemolyticus
Streptococcus viridans

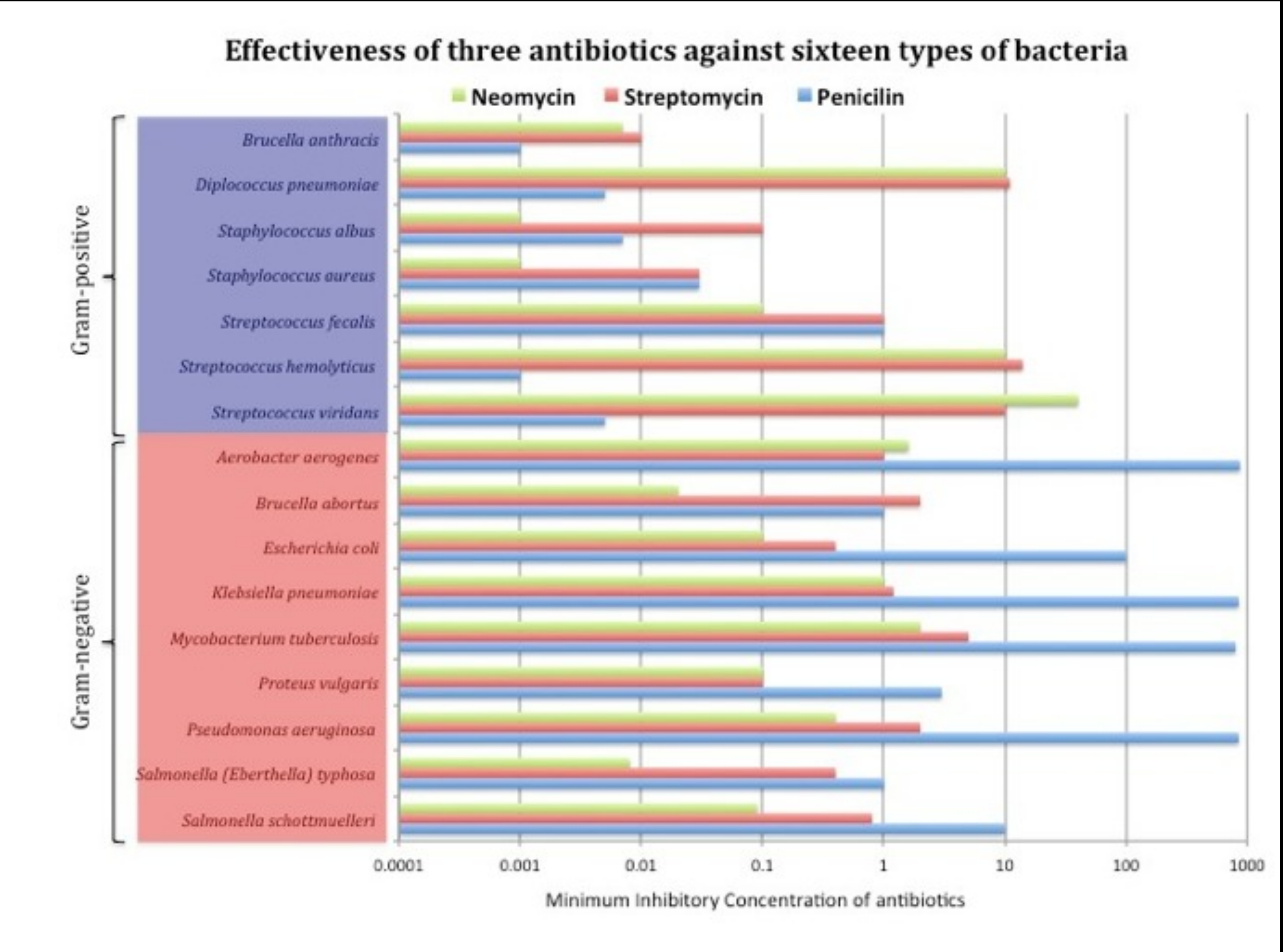

Concentrations of Antibiotics nessicary to fight common bacteria
Non-Staining
Staining
Neomycin
Penicilin
Streptomycin
1e-4
1e-3
1e-2
1e-1
1e+0
1e+1
1e+2
1e+3
µg/ml
2
5
870
1
14
40
Aerobacter aerogenes
Brucella abortus
Escherichia coli
Klebsiella pneumoniae
Mycobacterium tuberculosis
Proteus vulgaris
Pseudomonas aeruginosa
Salmonella (Eberthella) typhosa
Salmonella schottmuelleri
Brucella anthracis
Diplococcus pneumoniae
Staphylococcus albus
Staphylococcus aureus
Streptococcus fecalis
Streptococcus hemolyticus
Streptococcus viridans


Antibiotic Effectiveness Plot
Salmonella schottmuelleri
Salmonella (Eberthella) typhosa
Pseudomonas aeruginosa
Proteus vulgaris
Mycobacterium tuberculosis
Klebsiella pneumoniae
Escherichia coli
Brucella abortus
Aerobacter aerogenes
Streptococcus viridans
Streptococcus hemolyticus
Streptococcus fecalis
Staphylococcus aureus
Staphylococcus albus
Diplococcus pneumoniae
Brucella anthracis
Gram Staiing
Negative
Gram Staiing
Positive
X axis: Antibiotic
Effectiveness=$LOG_{10}\left(\frac{1}{MIC}\right)$
Bigger X represent better effectiveness
of the Antibiotic when applied to the
bacteria.
-6
-4
-2
4
6
8
Penicilin 0
Streptomycin
Neomycin 2

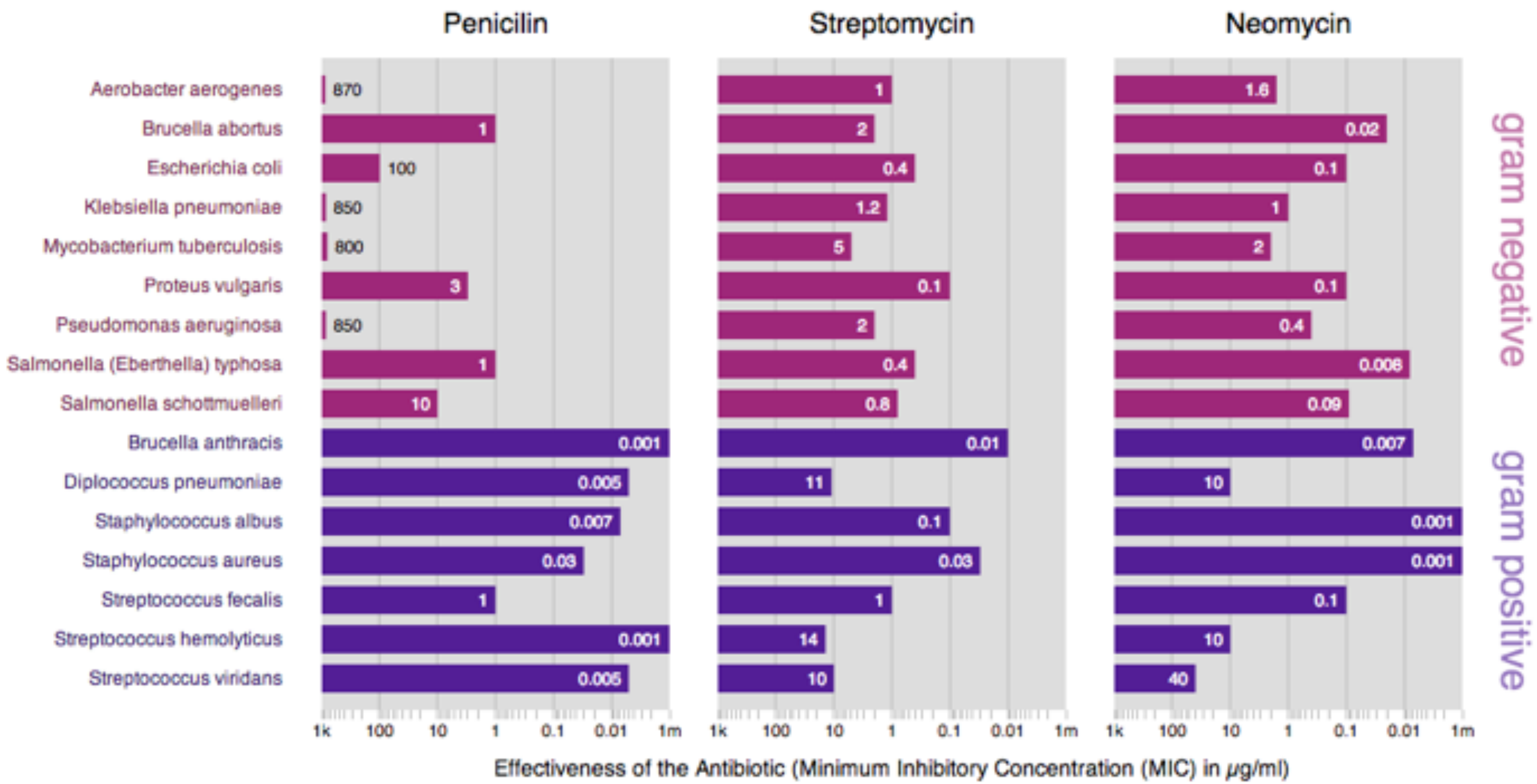


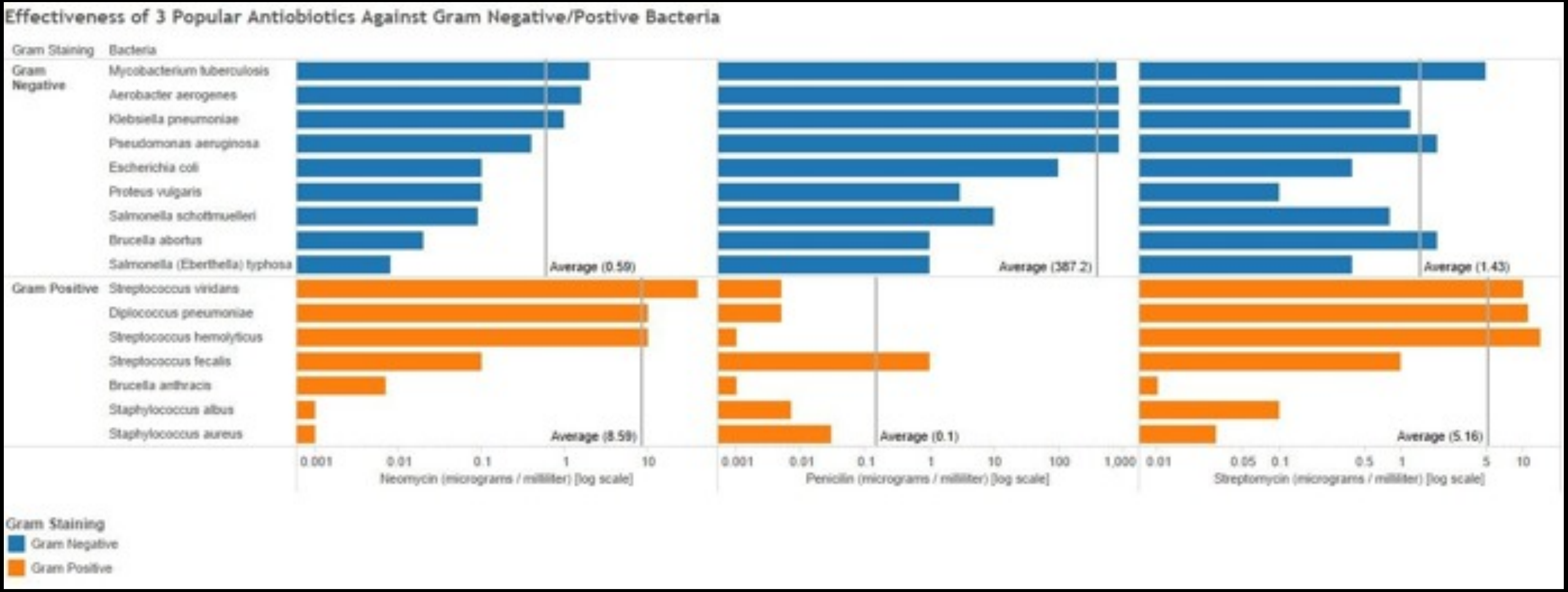
Streptococcus viridans
Streptococcus hemolyticus
Streptococcus fecalis
Staphylococcus aureus
Staphylococcus albus
Diplococcus pneumoniae
Brucella anthracis
Salmonella schottmuelleri
Salmonella (Eberthella) typhosa
Pseudomonas aeruginosa
Proteus vulgaris
Mycobacterium tuberculosis
Klebsiella pneumoniae
Escherichia coli
Brucella abortus
Aerobacter aerogenes
Neomycin
Streptomycin
Penicilin
1000
100
10
1
0.1
0.01
0.001
MIC

Minimum Inhibitory Concentration of Antibiotics (µg/ml)
0.0001
0.001
0.01
0.1
1
10
100
1000
Gram Stain Negative
Aerobacter aerogenes
Brucella abortus
Escherichia coli
Klebsiella pneumoniae
Mycobacterium tuberculosis
Proteus vulgaris
Pseudomonas aeruginosa
Salmonella (Eberthella) typhosa
Salmonella schottmuelleri
Mean (Gram Negative)
Gram Stain Positive
Brucella anthracis
Diplococcus pneumoniae
Staphylococcus albus
Staphylococcus aureus
Streptococcus fecalis
Streptococcus hemolyticus
Streptococcus viridans
Mean (Gram Positive)
Penicillin
Streptomycin
Neomycin


Effectiveness of three antibiotics against sixteen types of bacteria
Neomycin
Streptomycin
Penicilin
Gram-positive
Gram-negative
Brucella anthracis
Diplococcus pneumoniae
Staphylococcus albus
Staphylococcus aureus
Streptococcus fecalis
Streptococcus hemolyticus
Streptococcus viridans
Aerobacter aerogenes
Brucella abortus
Escherichia coli
Klebsiella pneumoniae
Mycobacterium tuberculosis
Proteus vulgaris
Pseudomonas aeruginosa
Salmonella (Eberthella) typhosa
Salmonella schottmuelleri
0.0001
0.001
0.01
0.1
1
10
100
1000
Minimum Inhibitory Concentration of antibiotics

Burtin's Antibiotics



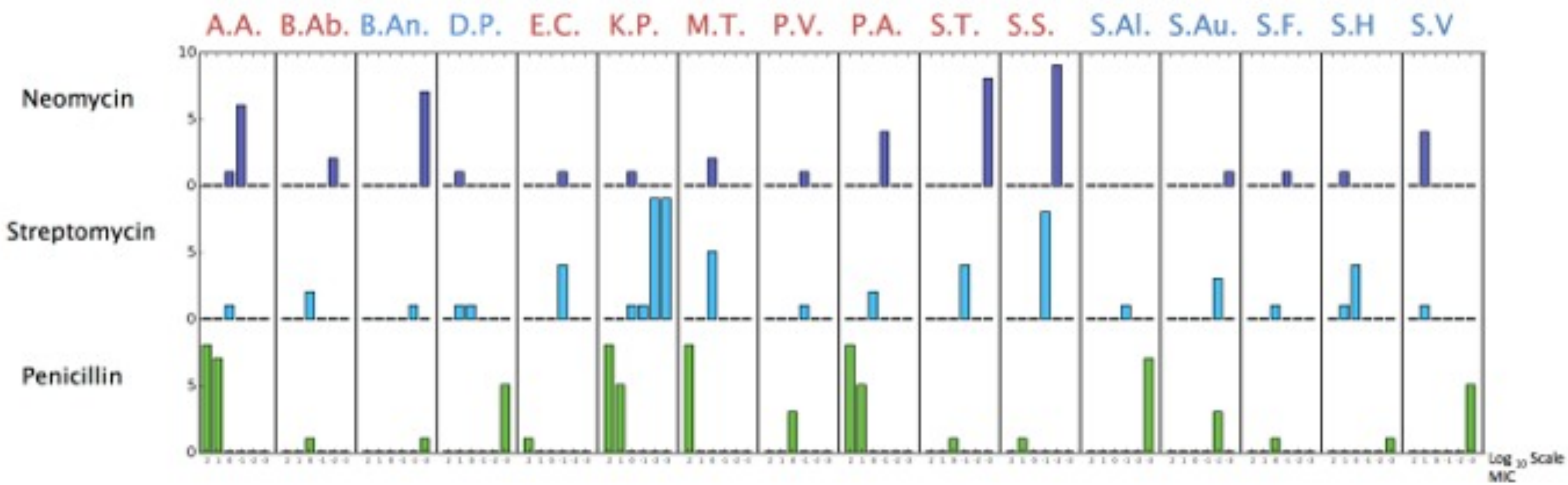


Effectiveness of 3 Popular Antiobiotics Against Gram Negative/Postive Bacteria
Gram Staining
Bacteria
Gram Negative
Mycobacterium tuberculosis
Aerobacter aerogenes
Klebsiella pneumoniae
Pseudomonas aeruginosa
Escherichia coli
Proteus vulgaris
Salmonella schottmuelleri
Brucella abortus
Salmonella (Eberthella) typhosa
Gram Positive
Streptococcus viridans
Diplococcus pneumoniae
Streptococcus hemolyticus
Streptococcus fecalis
Brucella anthracis
Staphylococcus albus
Staphylococcus aureus
Average (0.59)
Average (8.59)
Average (387.2)
Average (0.1)
Average (1.43)
Average (5.16)
0.001 0.01 0.1 1 10
Neomycin (micrograms / milliliter) [log scale]
0.001 0.01 0.1 1 10 100 1,000
Penicilin (micrograms / milliliter) [log scale]
0.01 0.05 0.1 0.5 1 5 10
Streptomycin (micrograms / milliliter) [log scale]
Gram Staining
Gram Negative
Gram Positive

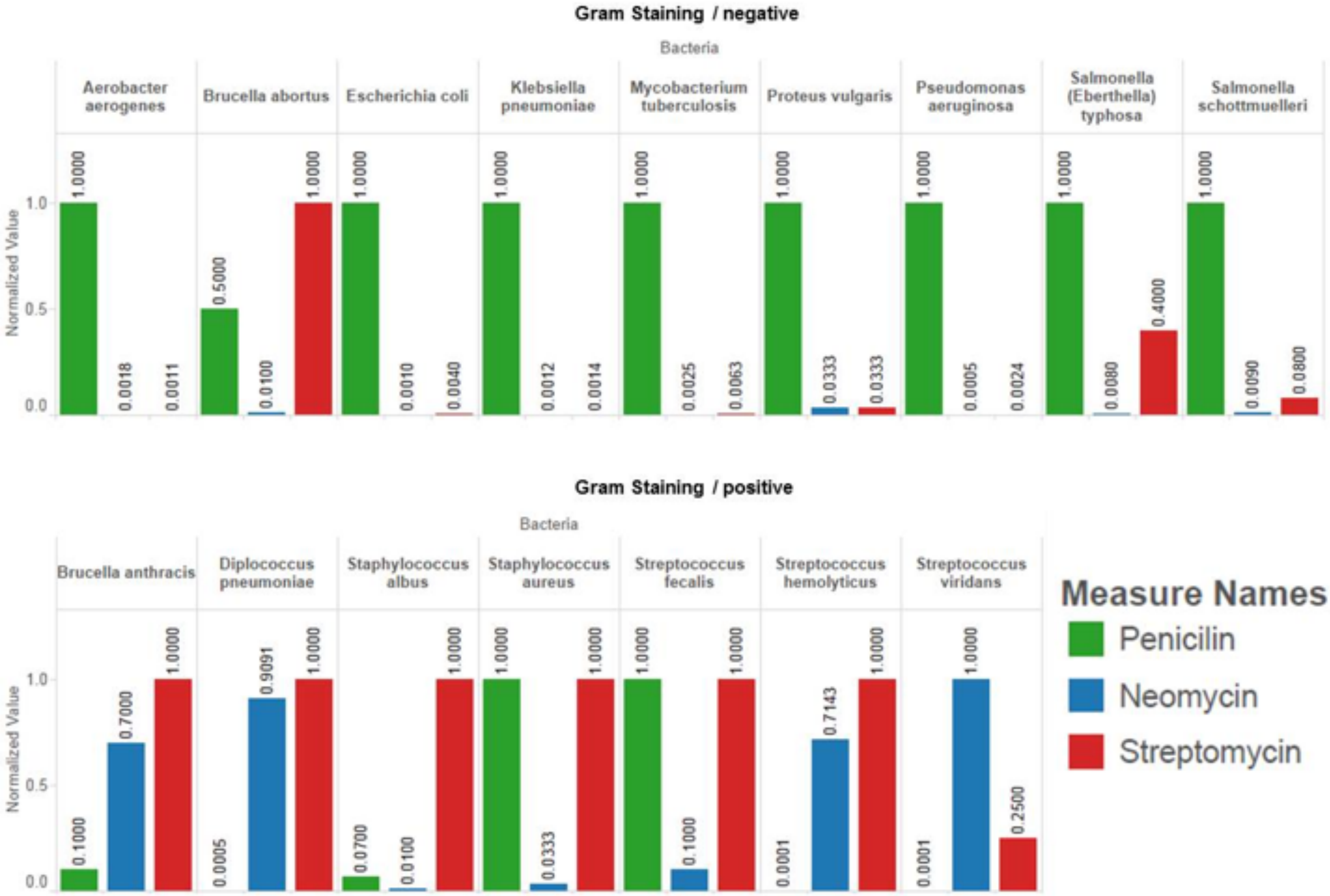
The Effectiveness of Antibiotics on Various Bacteria

Abbreviation	Bacteria
A.A.	Aerobacter aerogenes
B.Ab.	Brucella abortus
B.An.	Brucella anthracis
D.P.	Diplococcus pneumoniae
E.C.	Escherichia coli
K.P.	Klebsiella pneumoniae
M.T.	Mycobacterium tuberculosis
P.V.	Proteus vulgaris
P.A.	Pseudomonas aeruginosa
S.T.	Salmonella (Eberthella) typhosa
S.S.	Salmonella schottmuelleri
S.Al.	Staphylococcus albus
S.Au.	Staphylococcus aureus
S.F.	Streptococcus fecalis
S.H.	Streptococcus hemolyticus
S.V.	Streptococcus viridans

Gram Staining Negative
Gram Staining Positive

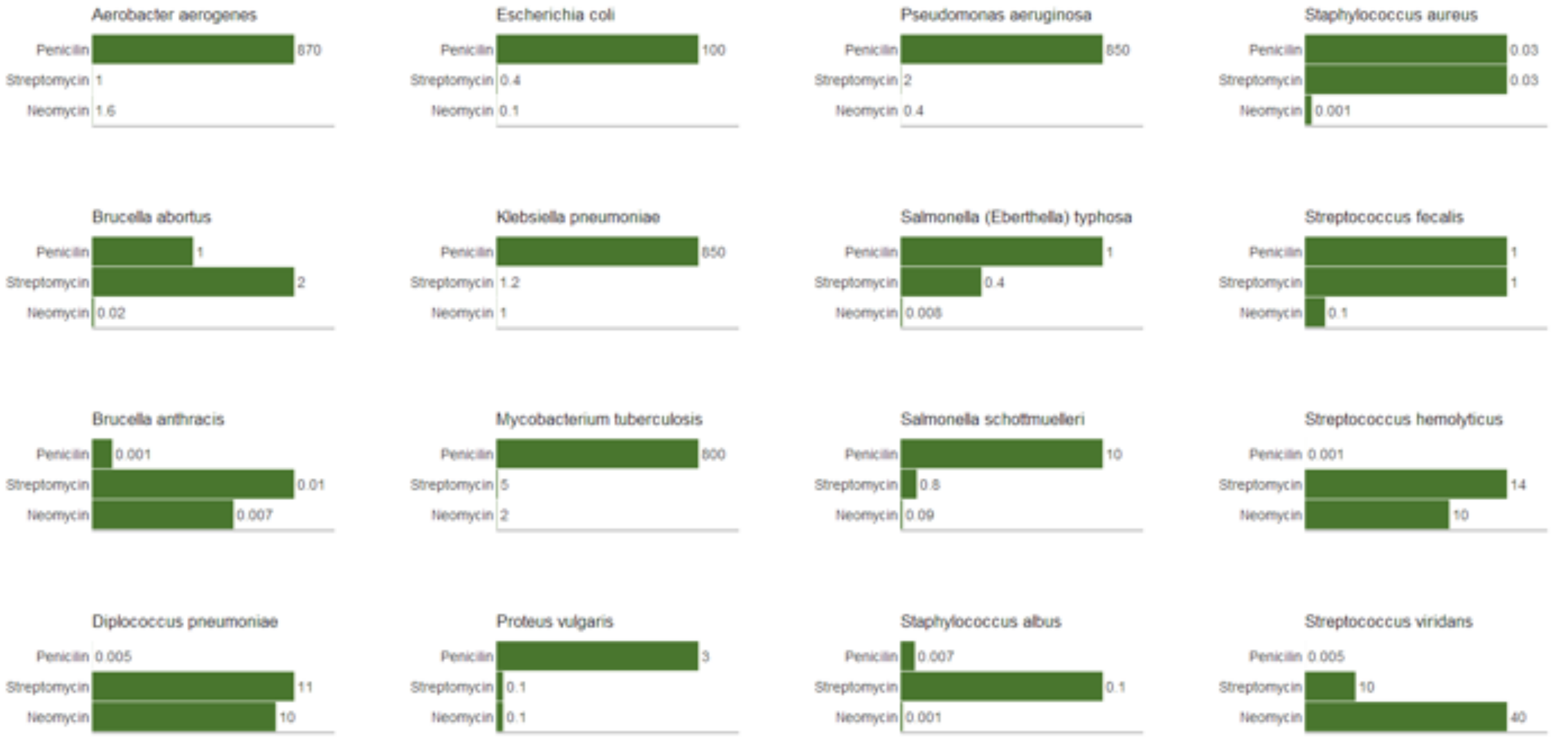


Effectiveness of 3 Antibiotics to 16 Bacterias

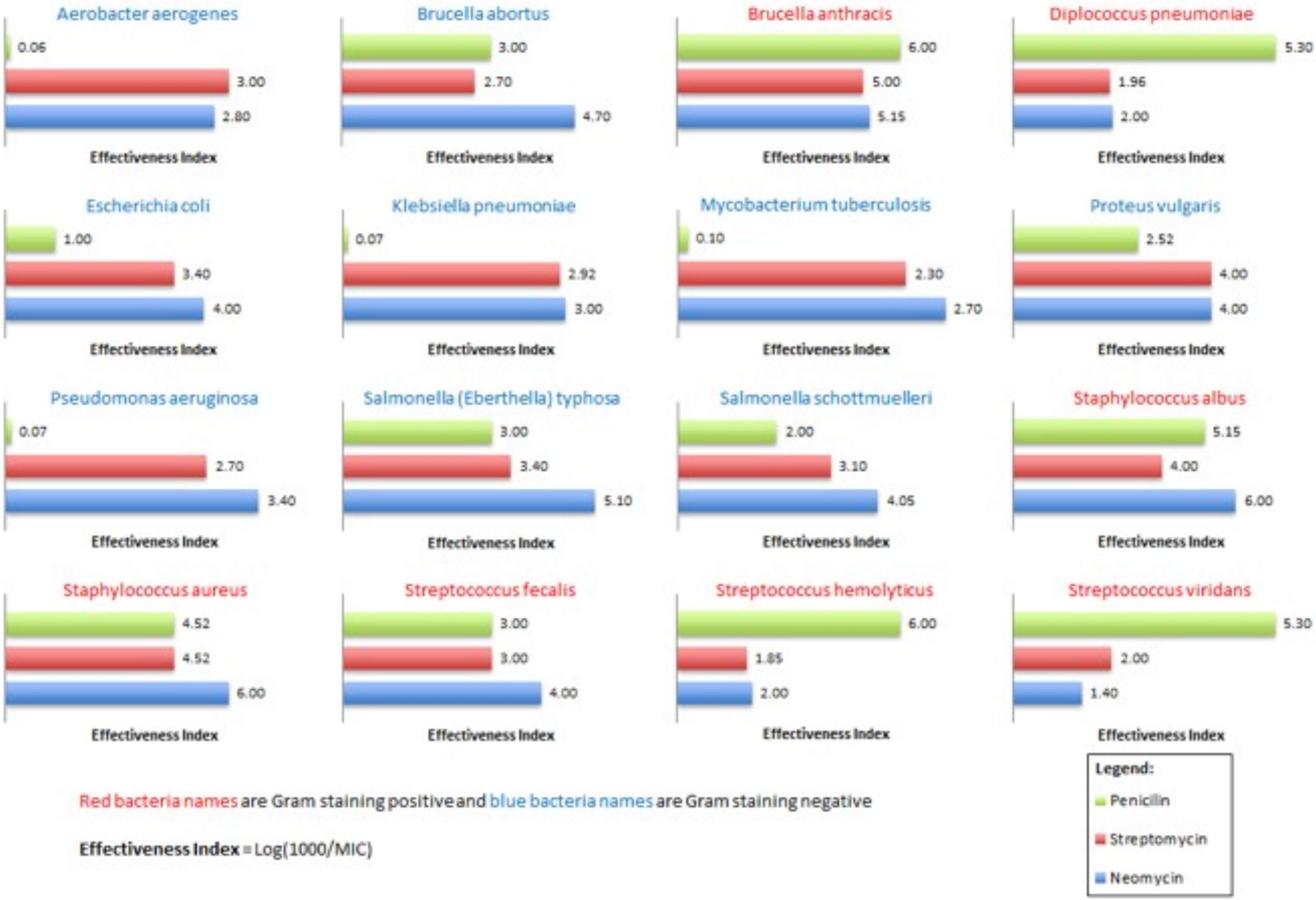


Minimum inhibitory concentration (MIC) normalized by the largest value of that bacteria

MIC of antibiotics on various bacteria



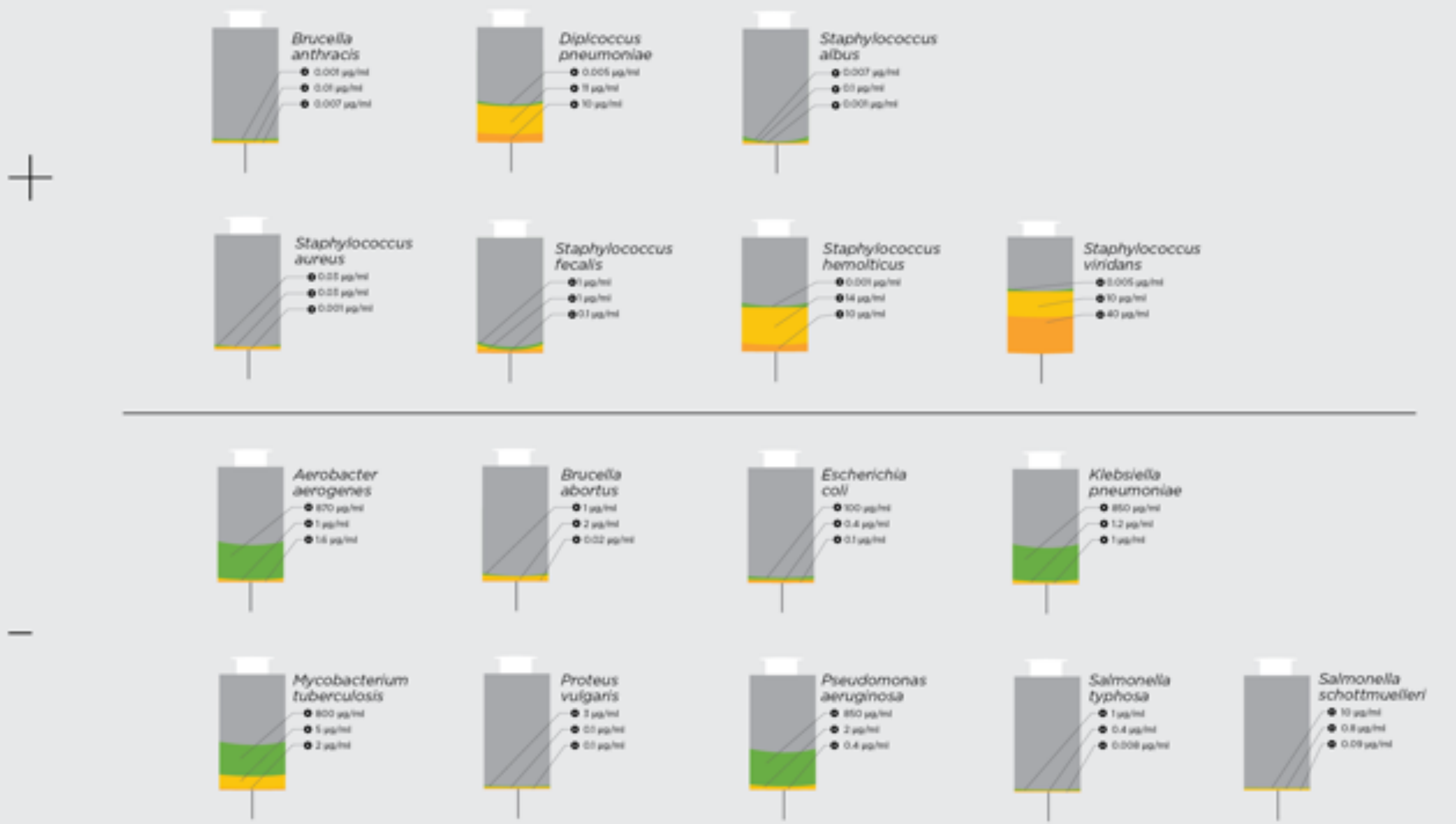
Antibiotic Effectiveness by Bacteria



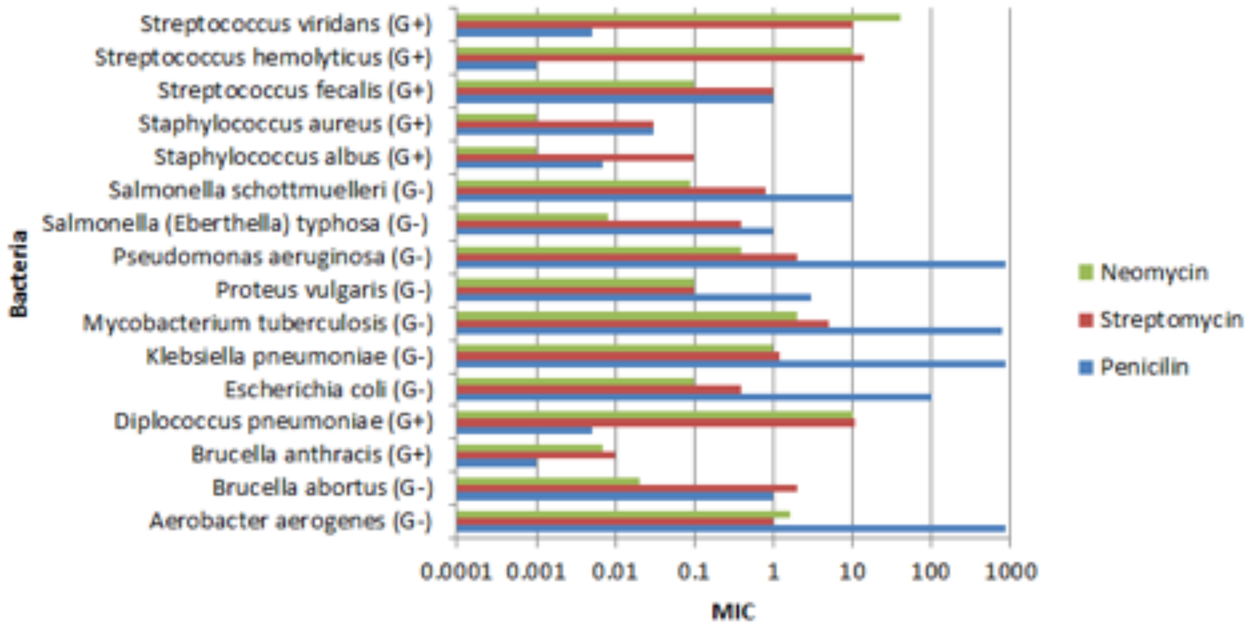
Red bacteria names are Gram staining positive and blue bacteria names are Gram staining negative

Effectiveness Index = Log(1000/MIC)

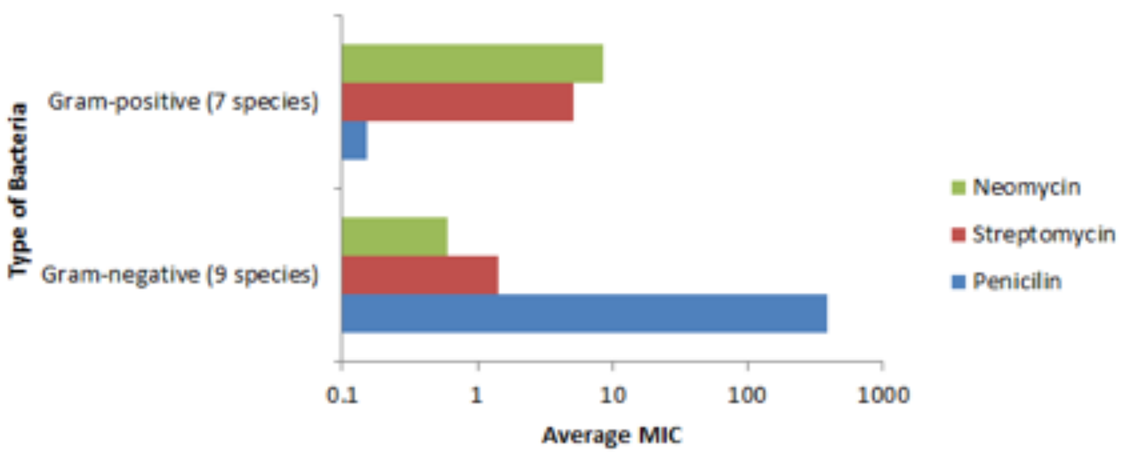
Antibiotics wwII

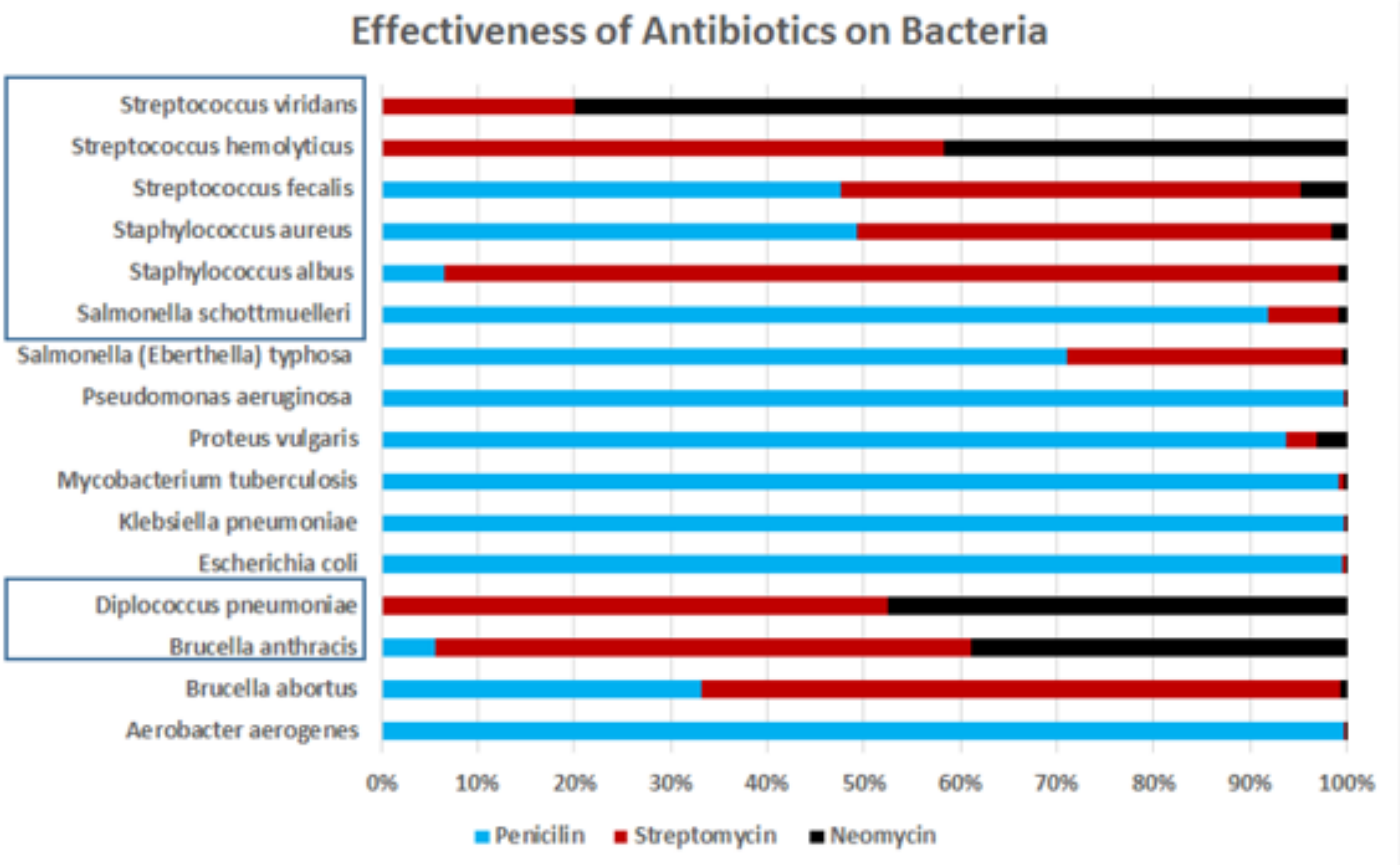


Minimum Inhibitory Concentration (MIC) of 3 Antibiotics on 16 Bacteria

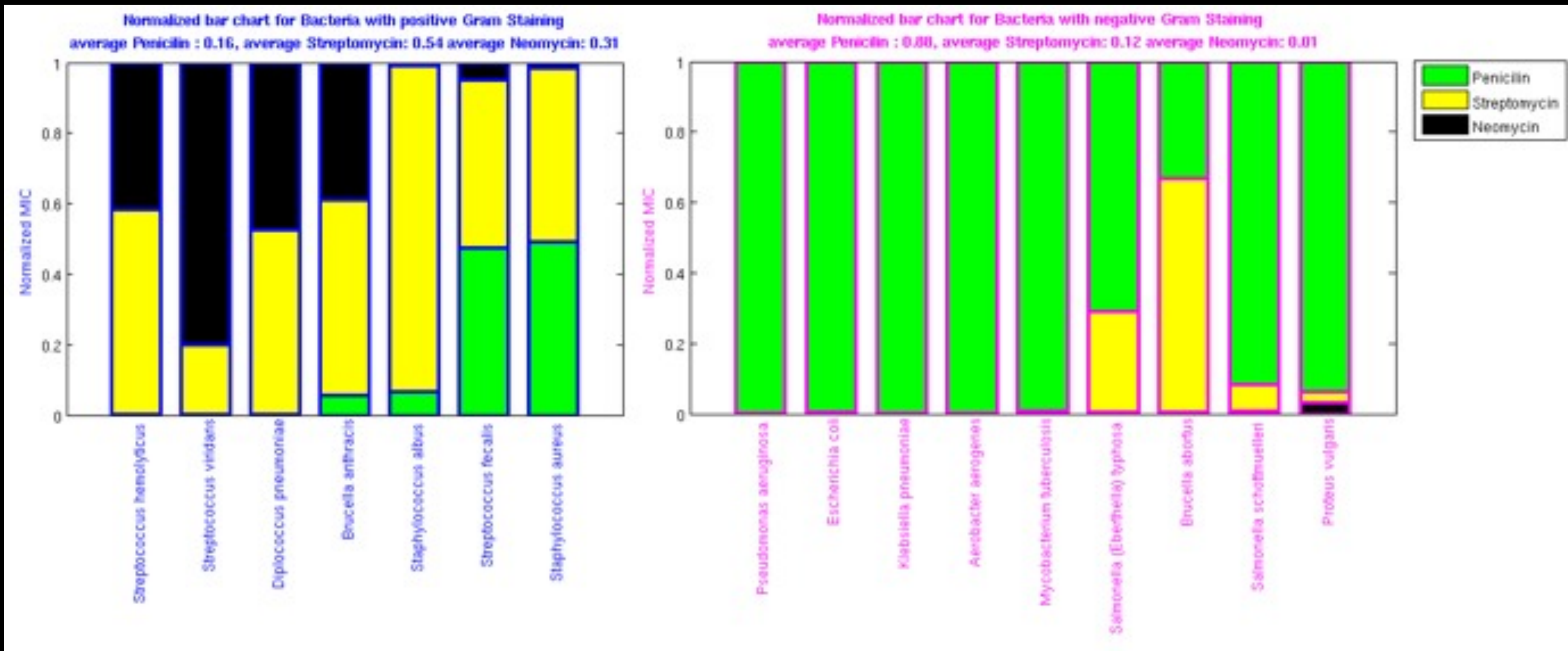


Average Minimum Inhibitory Concentration of Above Antibiotics by Type of Above Bacteria





Positive Gram Staining


Normalized bar chart for Bacteria with positive Gram Staining
average Penicilin : 0.16, average Streptomycin: 0.54 average Neomycin: 0.31
Normalized MIC
0
0.2
0.4
0.6
0.8
1
Streptococcus hemolyticus
Streptococcus viridans
Diplococcus pneumoniae
Brucella anthracis
Staphylococcus albus
Streptococcus fecalis
Staphylococcus aureus
Normalized bar chart for Bacteria with negative Gram Staining
average Penicilin : 0.88, average Streptomycin: 0.12 average Neomycin: 0.01
Normalized MIC
Pseudomonas aeruginosa
Escherichia coli
Klebsiella pneumoniae
Aerobacter aerogenes
Mycobacterium tuberculosis
Salmonella (Eberthella) typhosa
Brucella abortus
Salmonella schottmuelleri
Proteus vulgaris
Penicilin
Streptomycin
Neomycin

Effectiveness Comparison between Penicillin and Streptomycin / Neomycin

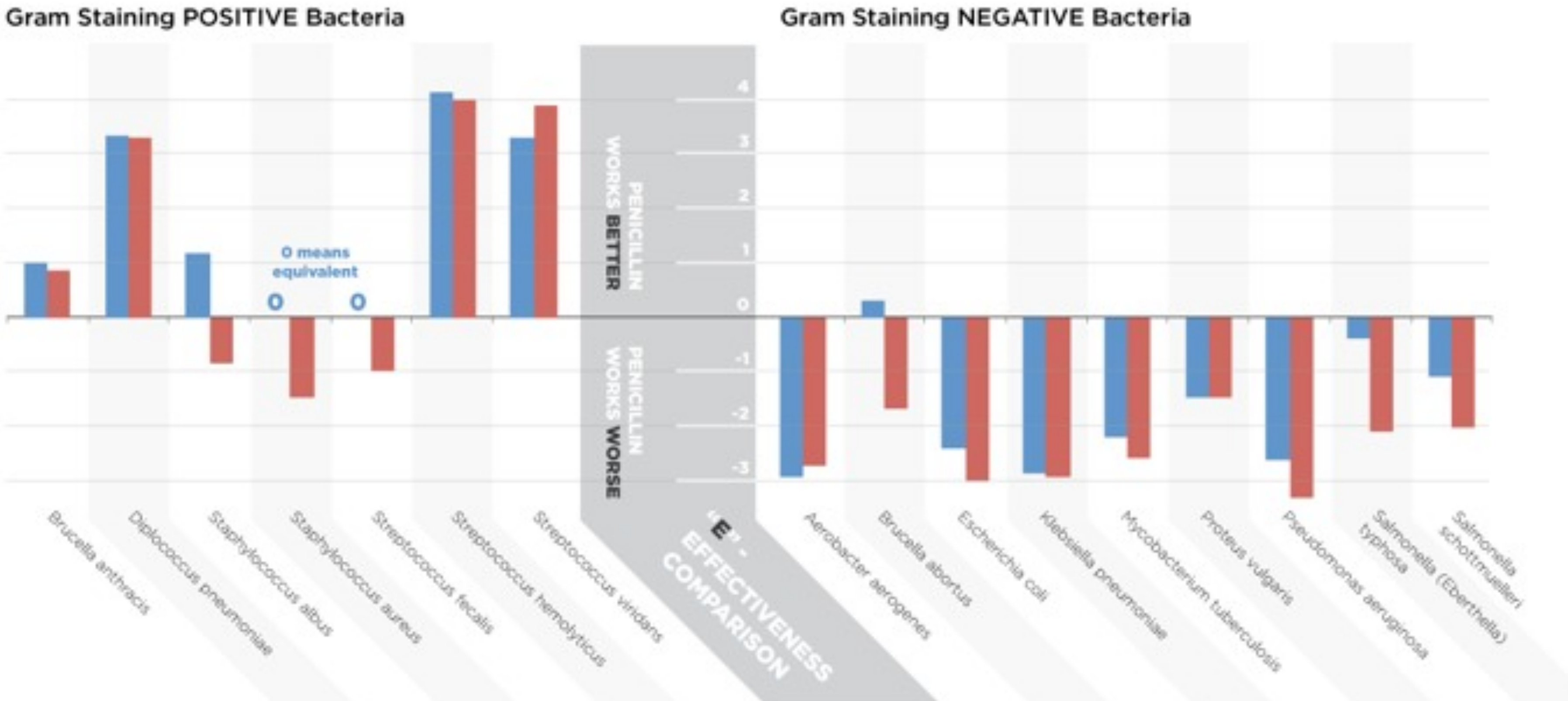
CSE 512 A1 | CHEN-HUNG WU

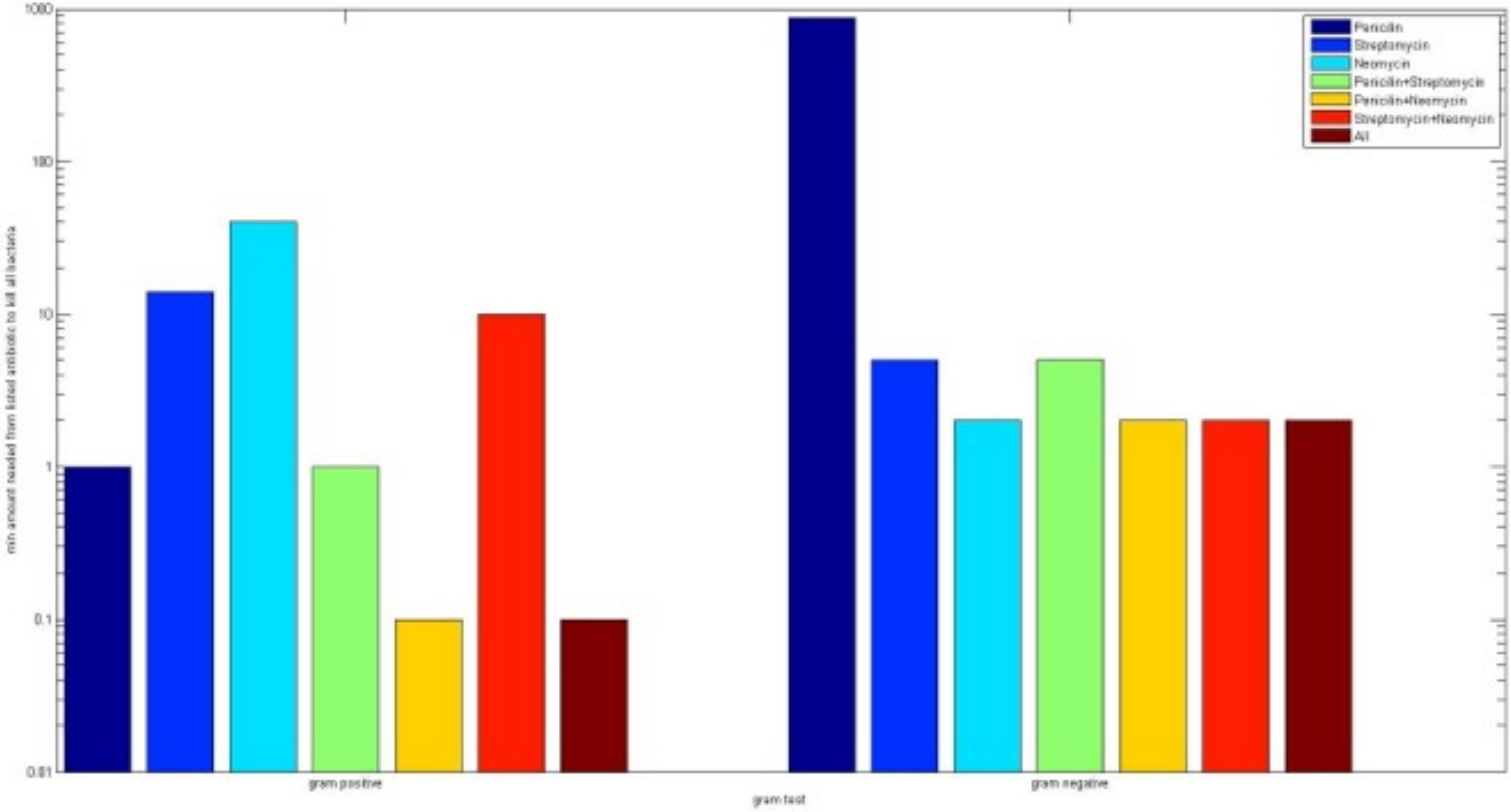
EFFECTIVENESS COMPARISON

$$E = \log\left(\frac{MIC_x}{MIC_{pen}}\right)$$

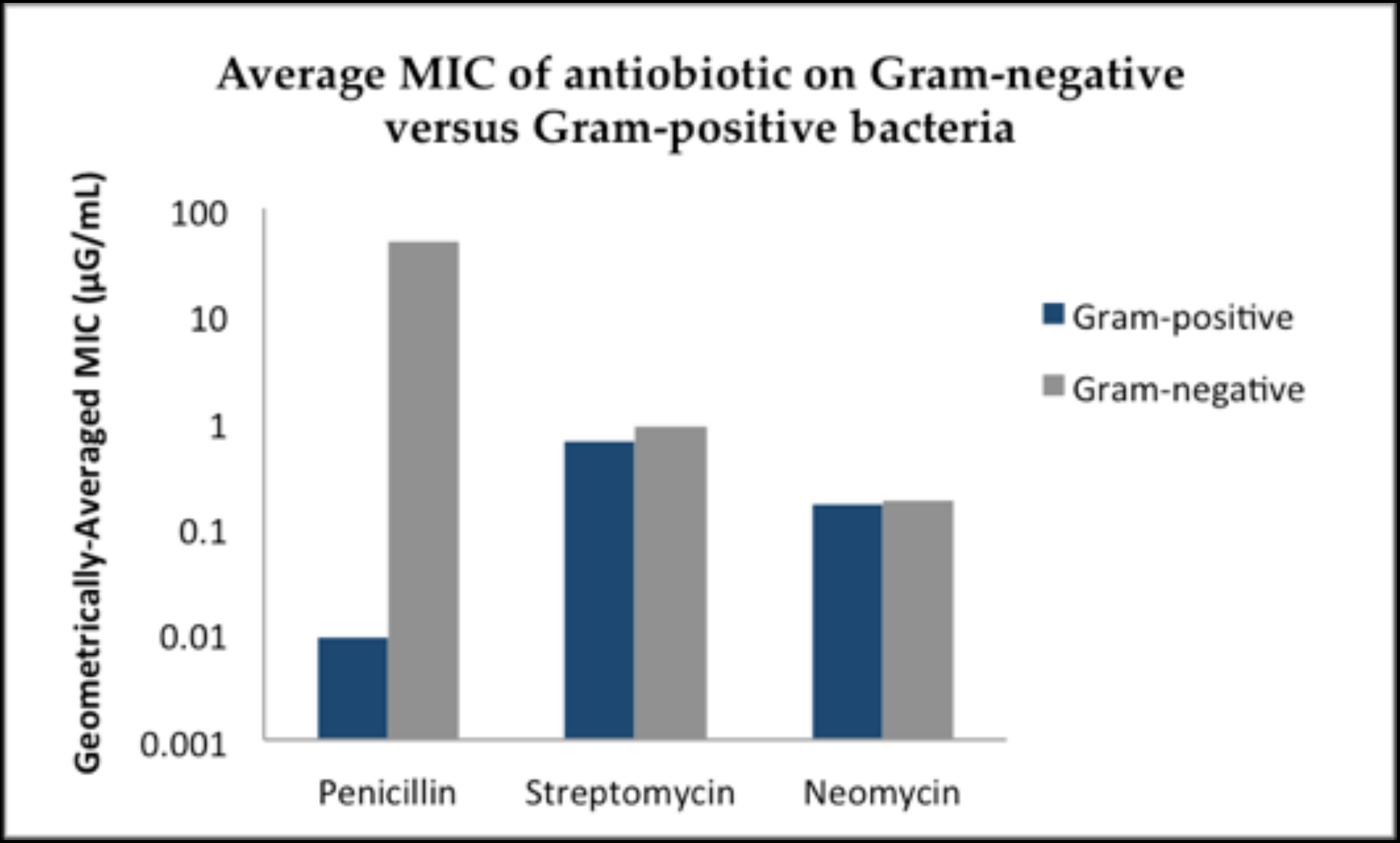
MIC_x: Minimum Inhibitory Concentration of x

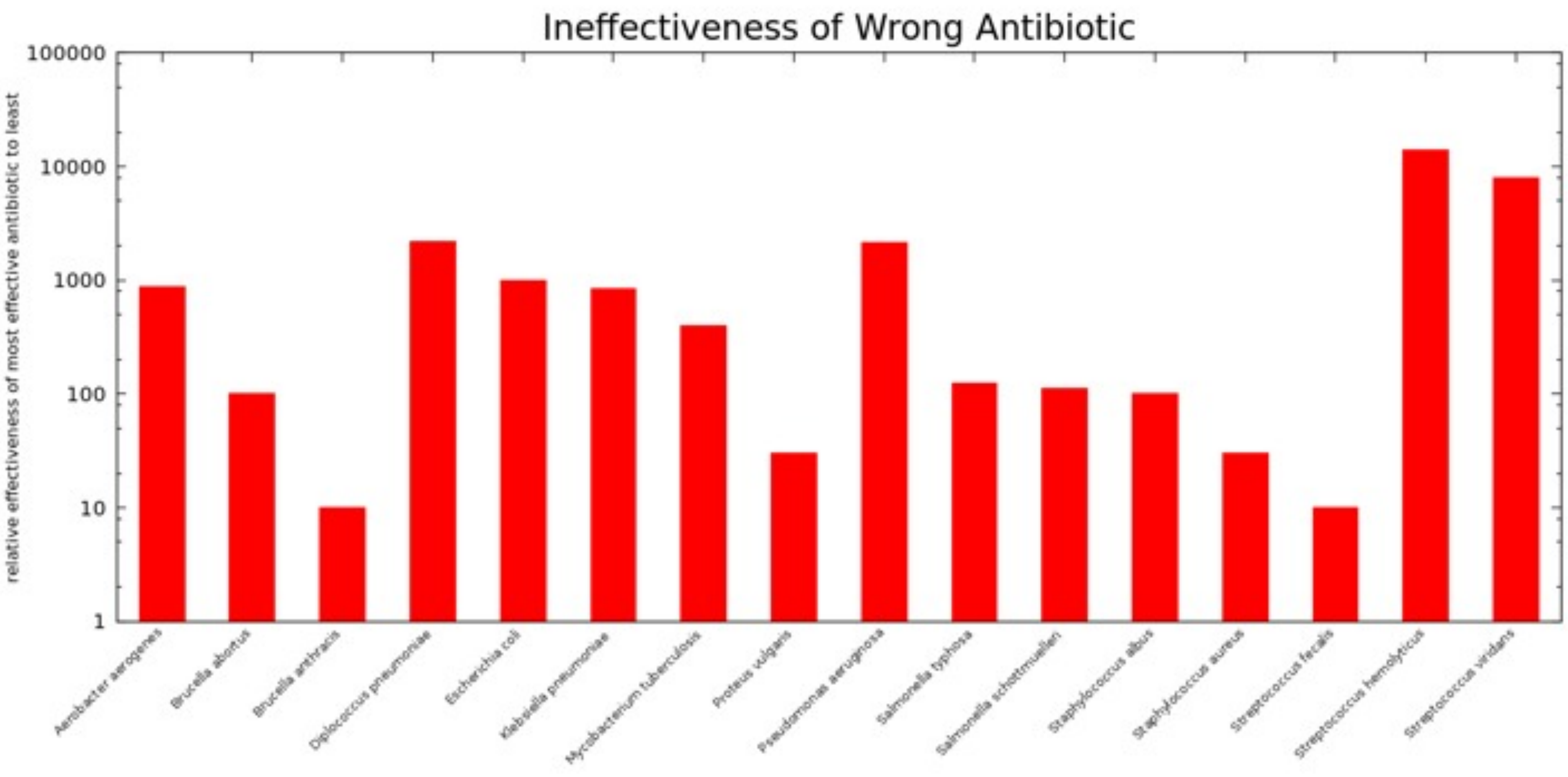
MIC_{pen}: Minimum Inhibitory Concentration of Penicillin



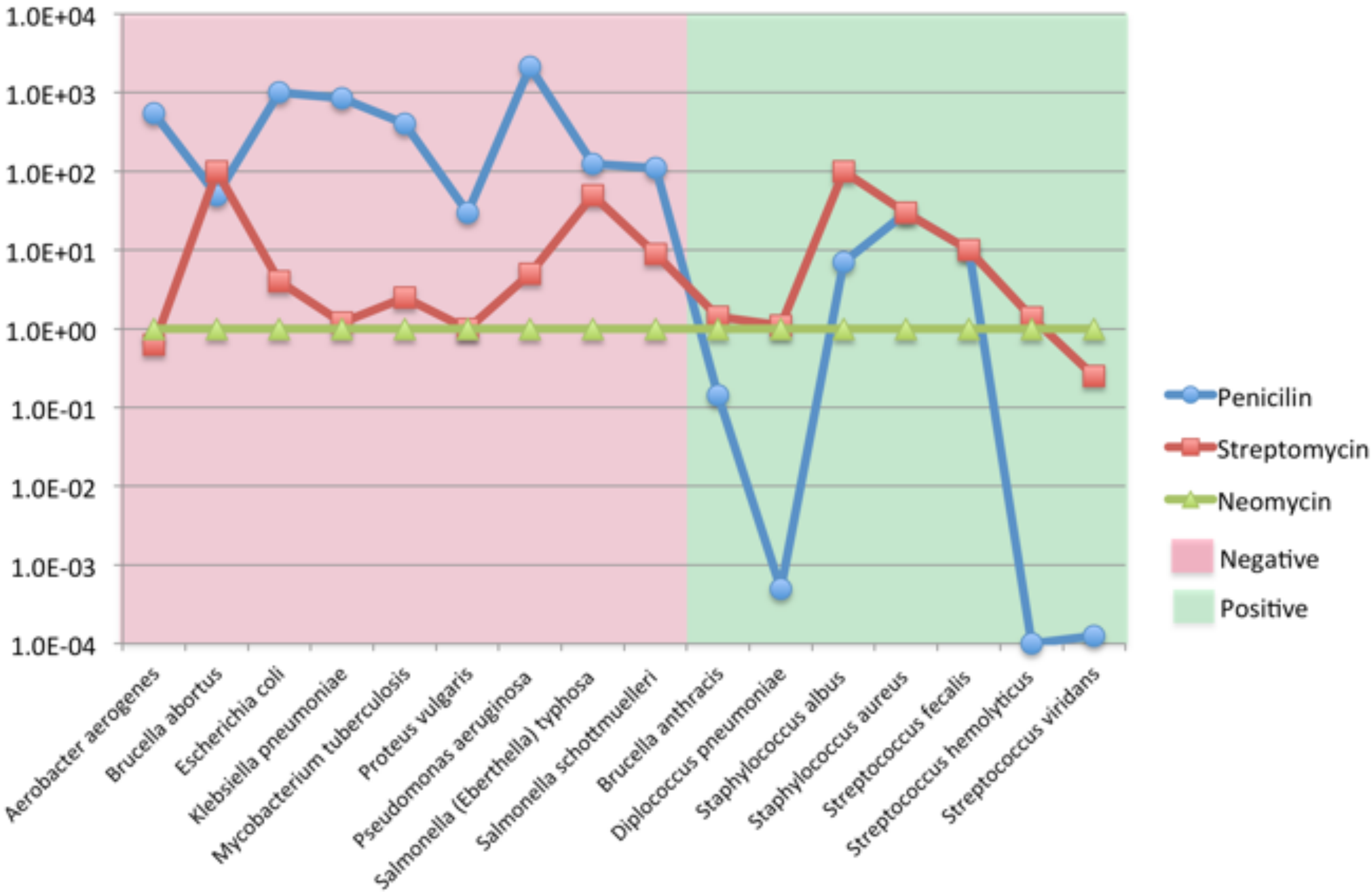


Penicilin
Streptomycin
Neomycin
Penicilin+Streptomycin
Penicilin+Neomycin
Streptomycin+Neomycin
All
1000
100
10
1
0.1
0.01
min amount needed from listed antibiotic to kill all bacteria
gram positive
gram negative
gram test

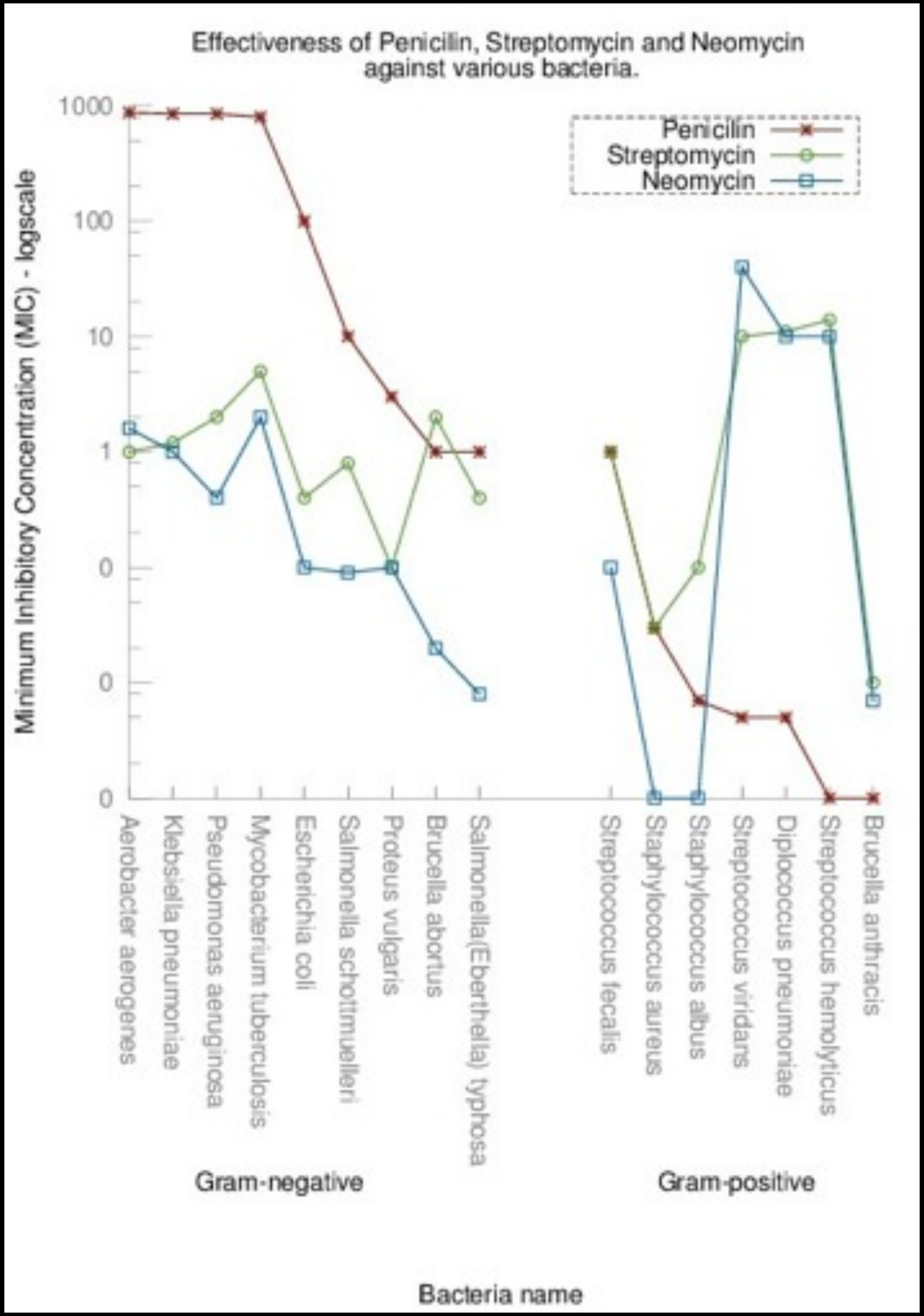

Average MIC of antiobiotic on Gram-negative versus Gram-positive bacteria
Geometrically-Averaged MIC (µG/mL)
100
10
1
0.1
0.01
0.001
Penicillin
Streptomycin
Neomycin
Gram-positive
Gram-negative


Ineffectiveness of Wrong Antibiotic
relative effectiveness of most effective antibiotic to least
100000
10000
1000
100
10
1
Aerobacter aerogenes
Brucella abortus
Brucella anthracis
Diplococcus pneumoniae
Escherichia coli
Klebsiella pneumoniae
Mycobacterium tuberculosis
Proteus vulgaris
Pseudomonas aeruginosa
Salmonella typhosa
Salmonella schottmuelleri
Staphylococcus albus
Staphylococcus aureus
Streptococcus fecalis
Streptococcus hemolyticus
Streptococcus viridans

Line Charts

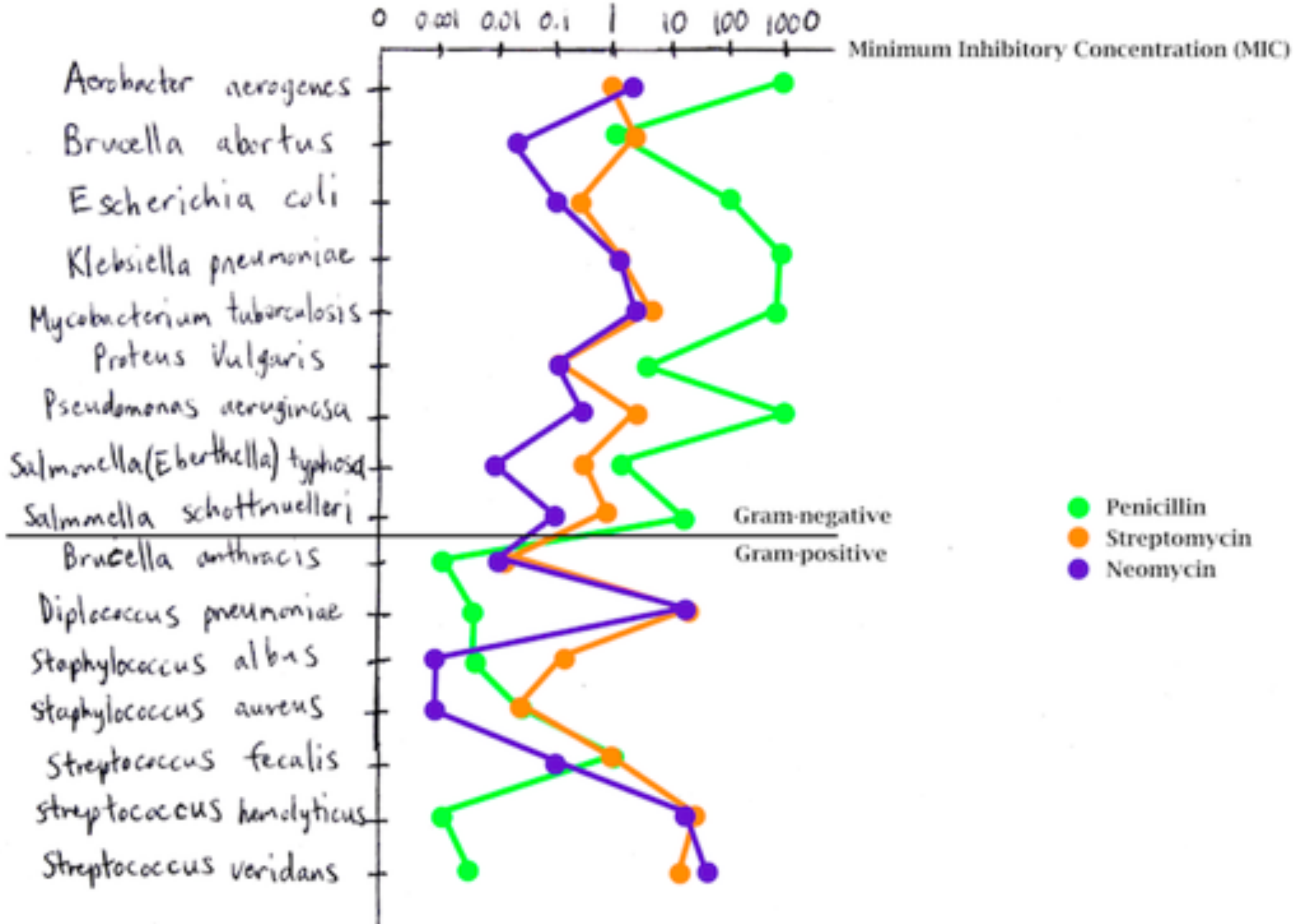


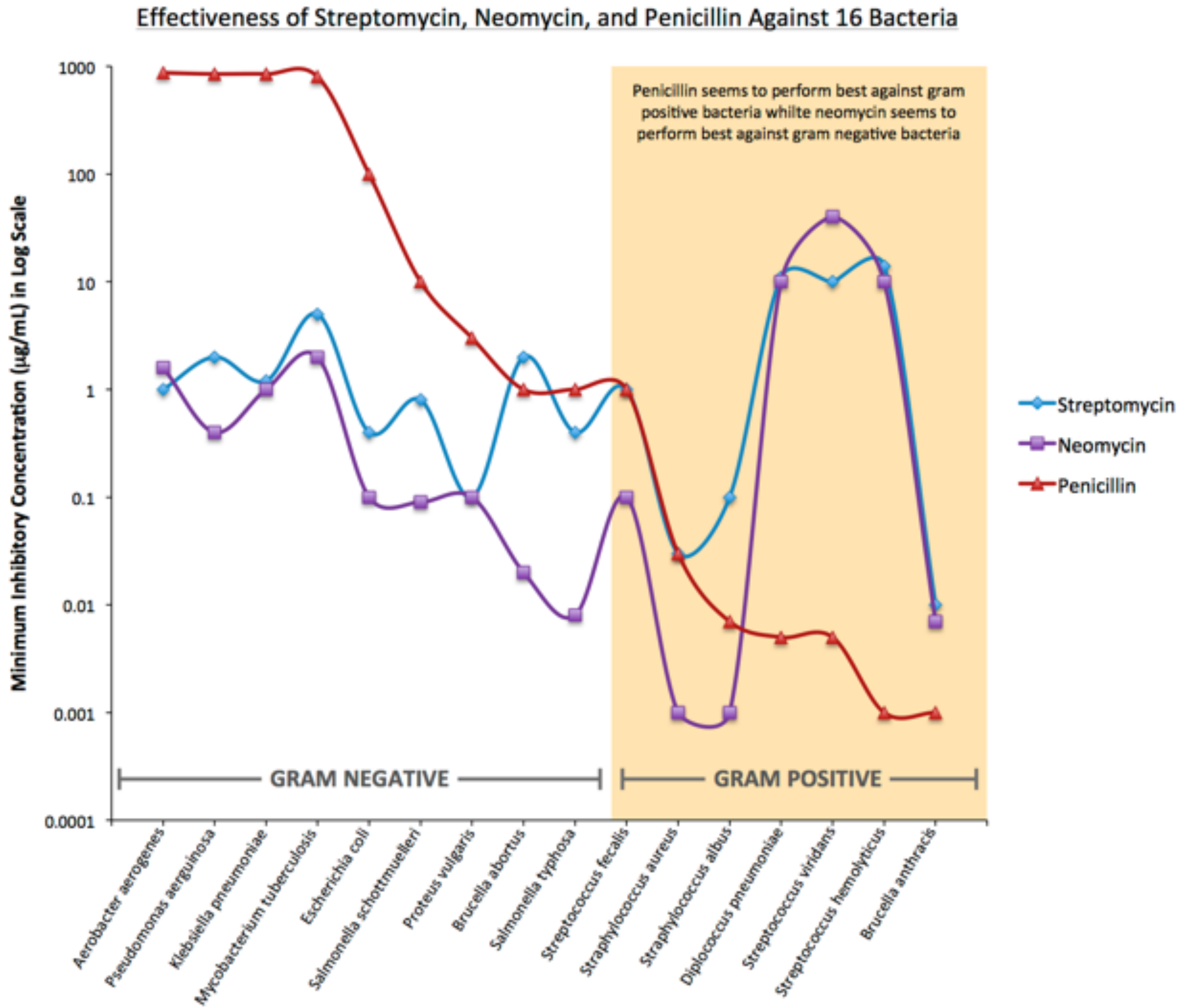
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Aerobacter aerogenes
Brucella abortus
Escherichia coli
Klebsiella pneumoniae
Mycobacterium tuberculosis
Proteus vulgaris
Pseudomonas aeruginosa
Salmonella (Eberthella) typhosa
Salmonella schottmuelleri
Brucella anthracis
Diplococcus pneumoniae
Staphylococcus albus
Staphylococcus aureus
Streptococcus fecalis
Streptococcus hemolyticus
Streptococcus viridans
Penicilin
Streptomycin
Neomycin
Negative
Positive

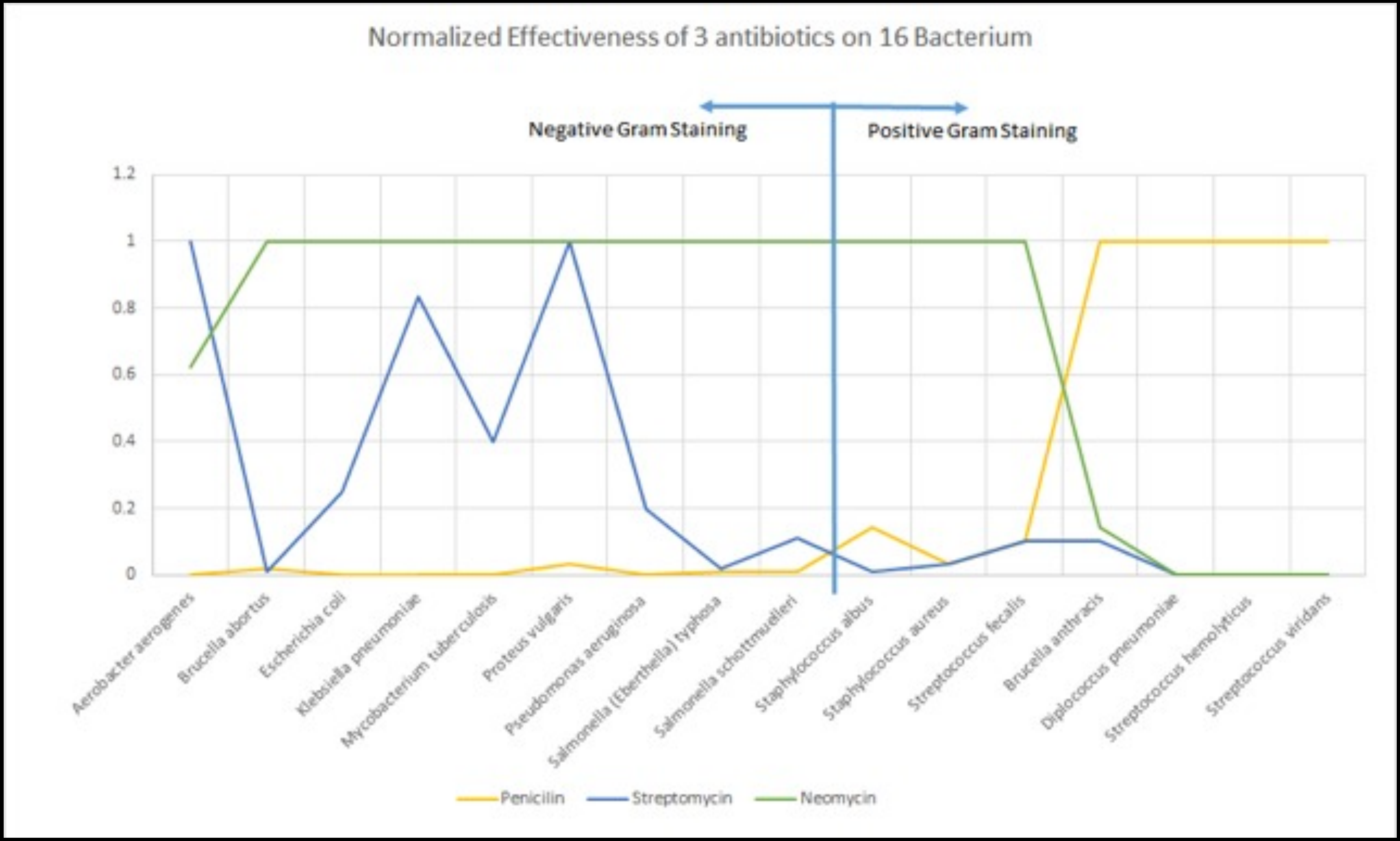


Effectiveness of Penicilin, Streptomycin and Neomycin against various bacteria.
Penicilin
Streptomycin
Neomycin
Minimum Inhibitory Concentration (MIC) - logscale
1000
100
10
1
0
0
0
Aerobacter aerogenes
Klebsiella pneumoniae
Pseudomonas aeruginosa
Mycobacterium tuberculosis
Escherichia coli
Salmonella schottmuelleri
Proteus vulgaris
Brucella abortus
Salmonella(Eberthella) typhosa
Streptococcus fecalis
Staphylococcus aureus
Staphylococcus albus
Streptococcus viridans
Diplococcus pneumoniae
Streptococcus hemolyticus
Brucella anthracis
Gram-negative
Gram-positive
Bacteria name

Measuring the effectiveness of popular antibiotics on various bacteria

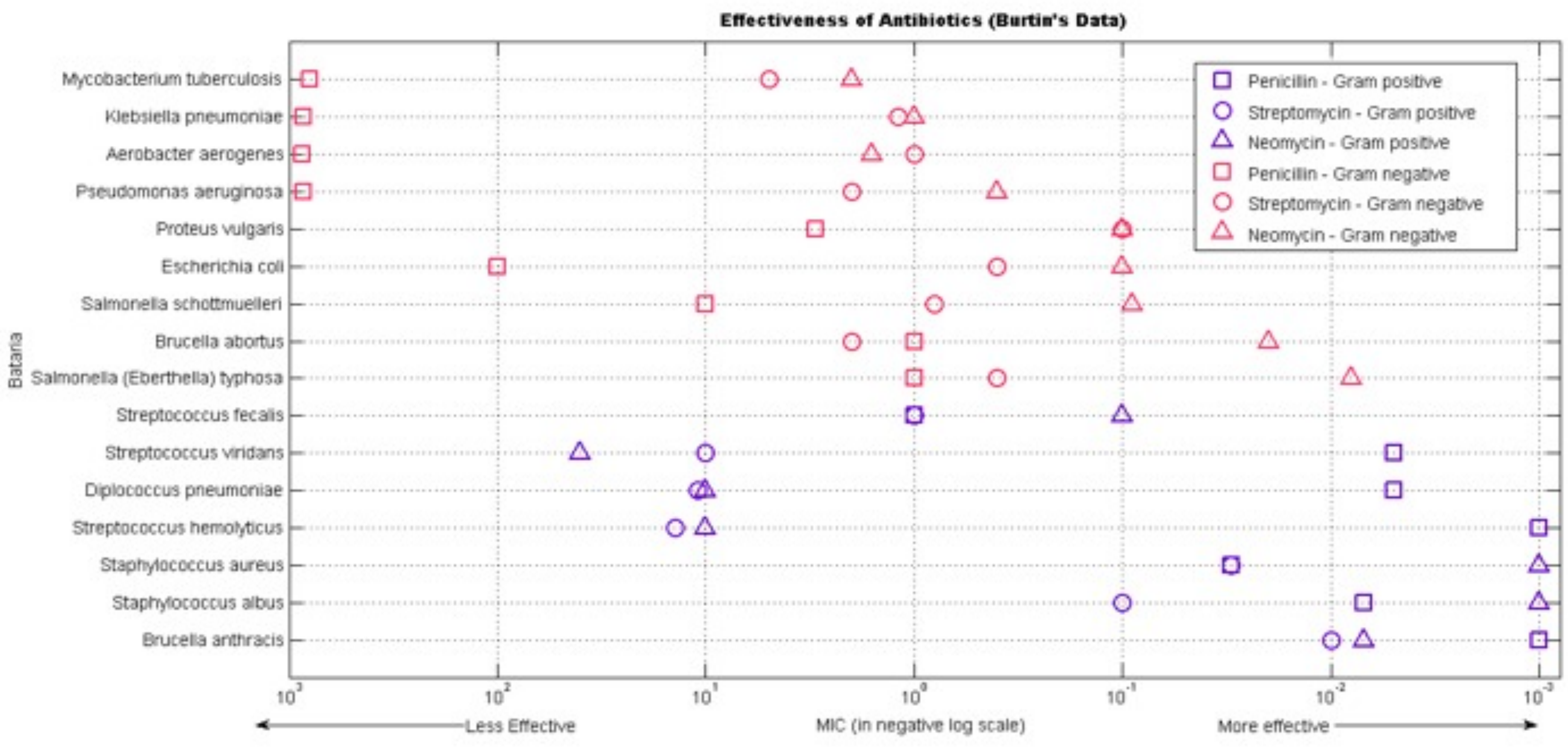



Effectiveness of Streptomycin, Neomycin, and Penicillin Against 16 Bacteria
Minimum Inhibitory Concentration (µg/mL) in Log Scale
1000
100
10
1
0.1
0.01
0.001
0.0001
Penicillin seems to perform best against gram positive bacteria whilte neomycin seems to perform best against gram negative bacteria
GRAM NEGATIVE
GRAM POSITIVE
Streptomycin
Neomycin
Penicillin
Aerobacter aerogenes
Pseudomonas aerguinosa
Klebsiella pneumoniae
Mycobacterium tuberculosis
Escherichia coli
Salmonella schottmuelleri
Proteus vulgaris
Brucella abortus
Salmonella typhosa
Streptococcus fecalis
Straphylococcus aureus
Straphylococcus albus
Diplococcus pneumoniae
Streptococcus viridans
Streptococcus hemolyticus
Brucella anthracis

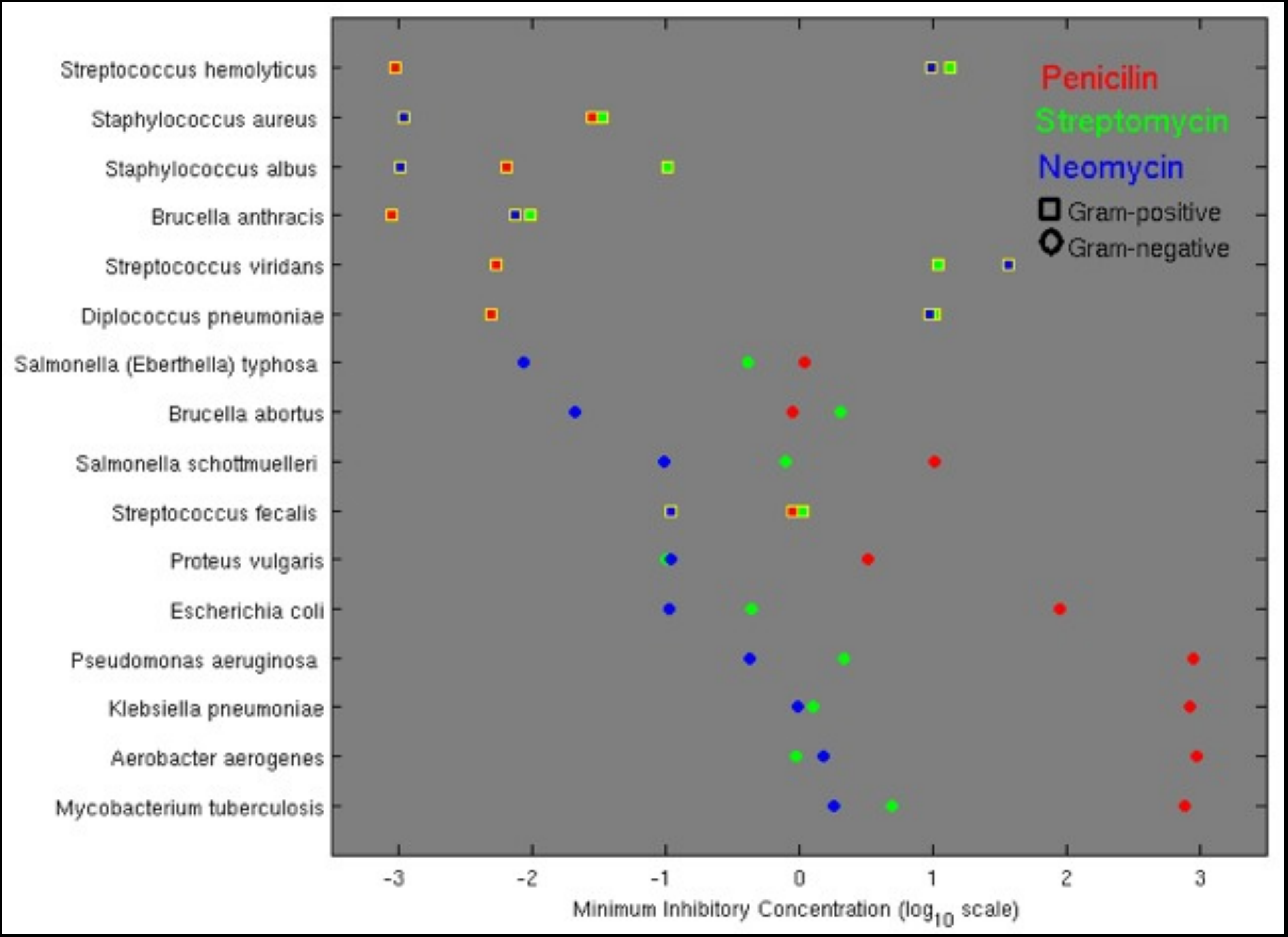


Normalized Effectiveness of 3 antibiotics on 16 Bacterium
Negative Gram Staining
Positive Gram Staining
1.2
1
0.8
0.6
0.4
0.2
0
Aerobacter aerogenes
Brucella abortus
Escherichia coli
Klebsiella pneumoniae
Mycobacterium tuberculosis
Proteus vulgaris
Pseudomonas aeruginosa
Salmonella (Eberthella) typhosa
Salmonella schottmuelleri
Staphylococcus albus
Staphylococcus aureus
Streptococcus fecalis
Brucella anthracis
Diplococcus pneumoniae
Streptococcus hemolyticus
Streptococcus viridans
Penicilin
Streptomycin
Neomycin

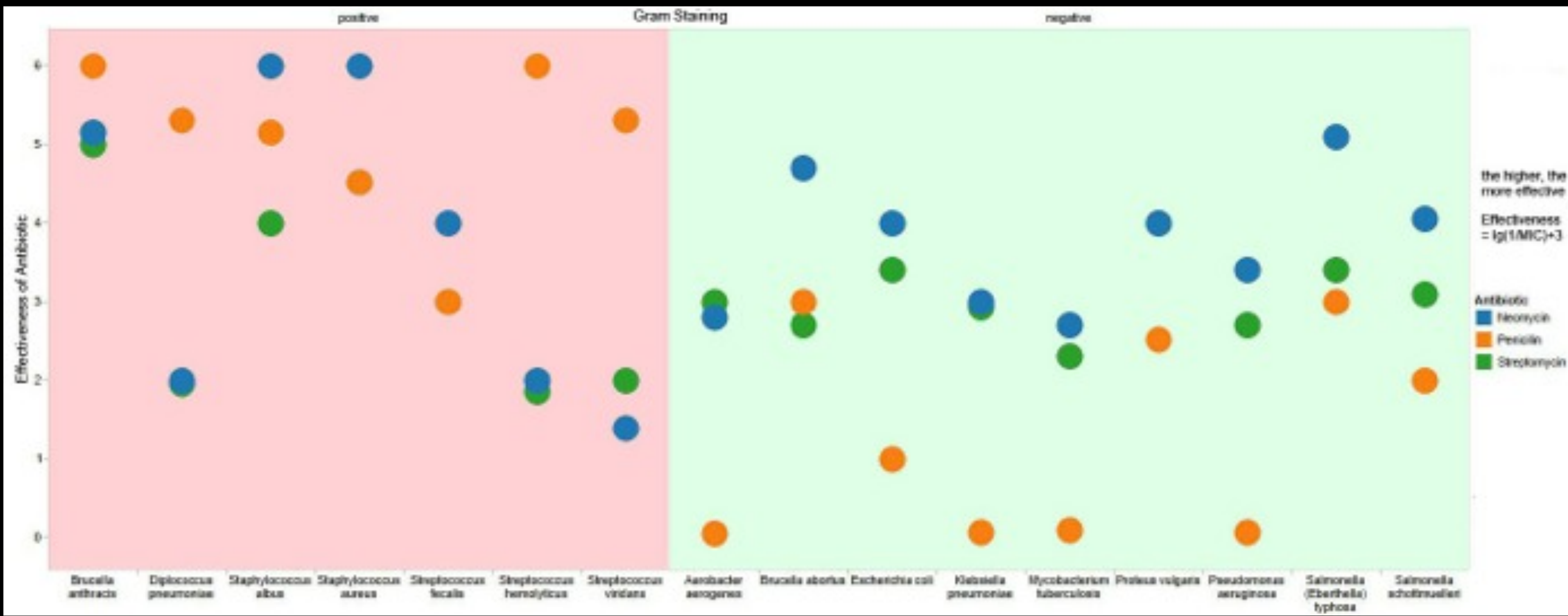
Dot Plots



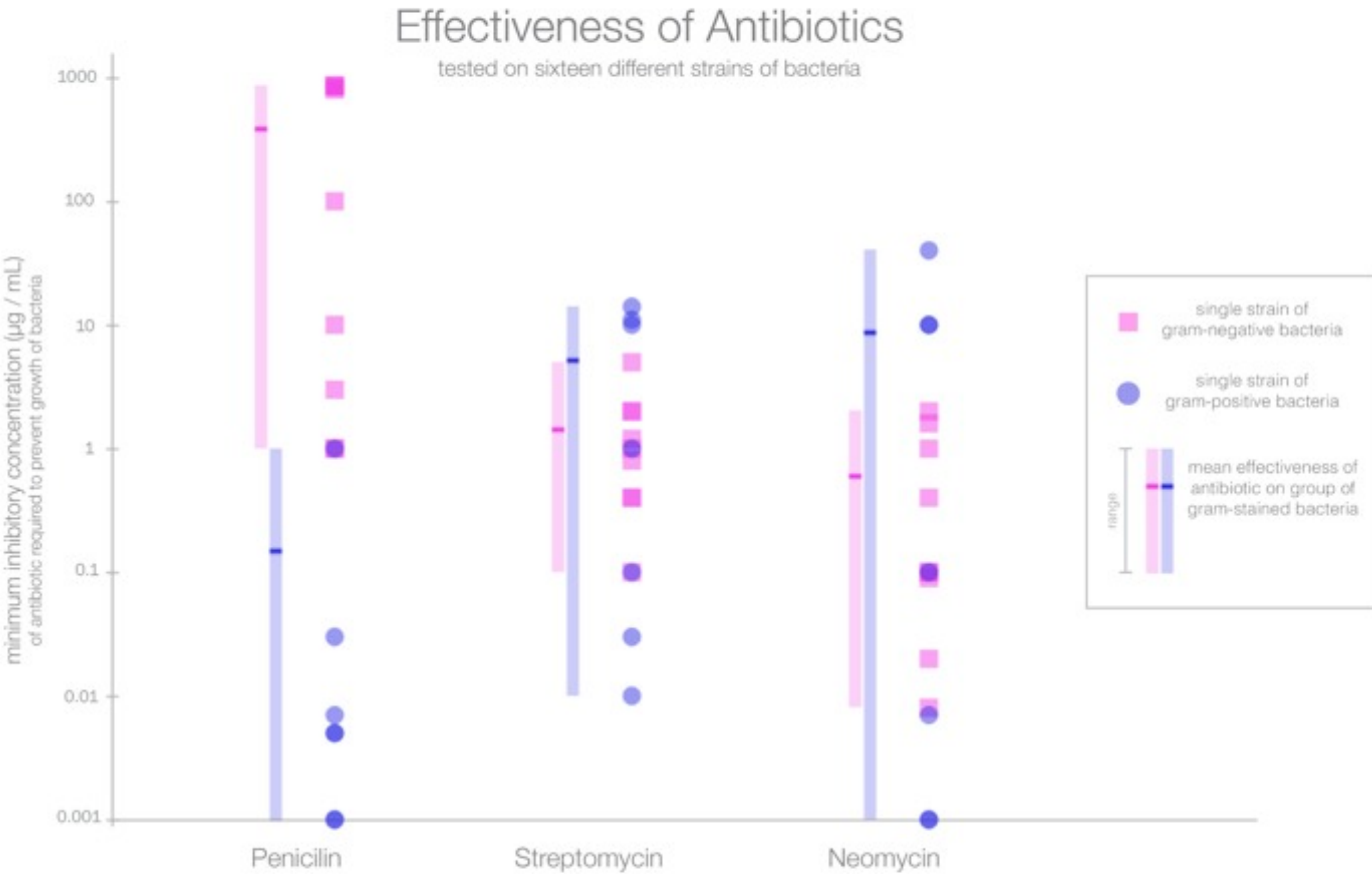
Effectiveness of Antibiotics (Burtin's Data)
Penicillin - Gram positive
Streptomycin - Gram positive
Neomycin - Gram positive
Penicillin - Gram negative
Streptomycin - Gram negative
Neomycin - Gram negative
Mycobacterium tuberculosis
Klebsiella pneumoniae
Aerobacter aerogenes
Pseudomonas aeruginosa
Proteus vulgaris
Escherichia coli
Salmonella schottmuelleri
Brucella abortus
Salmonella (Eberthella) typhosa
Streptococcus fecalis
Streptococcus viridans
Diplococcus pneumoniae
Streptococcus hemolyticus
Staphylococcus aureus
Staphylococcus albus
Brucella anthracis
Bataria
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
Less Effective
MIC (in negative log scale)
More effective



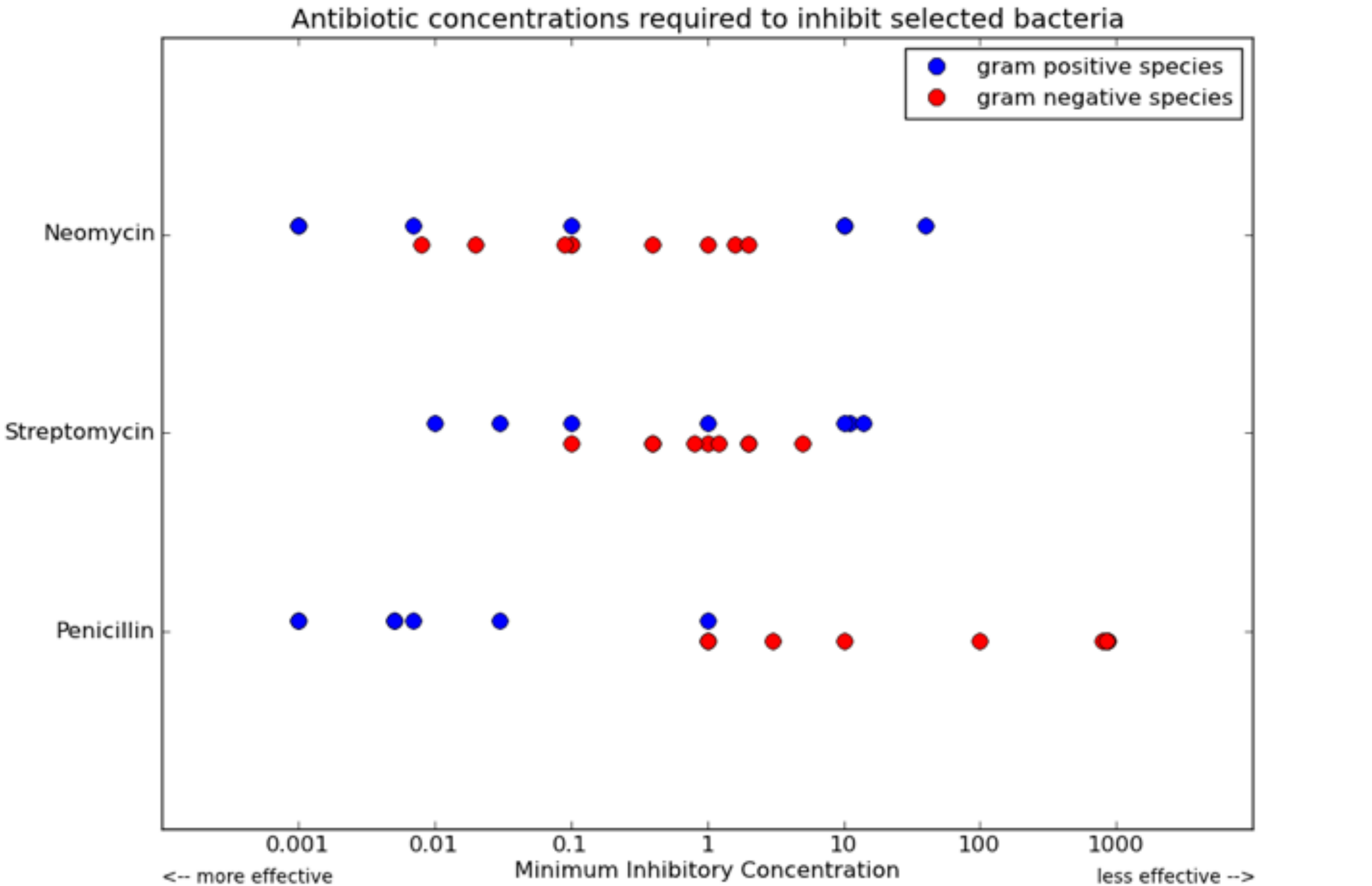
Streptococcus hemolyticus
Staphylococcus aureus
Staphylococcus albus
Brucella anthracis
Streptococcus viridans
Diplococcus pneumoniae
Salmonella (Eberthella) typhosa
Brucella abortus
Salmonella schottmuelleri
Streptococcus fecalis
Proteus vulgaris
Escherichia coli
Pseudomonas aeruginosa
Klebsiella pneumoniae
Aerobacter aerogenes
Mycobacterium tuberculosis
Penicilin
Streptomycin
Neomycin
Gram-positive
Gram-negative
-3
-2
-1
0
1
2
3
Minimum Inhibitory Concentration (log10 scale)


Gram Staining
positive
negative
Effectiveness of Antibiotic
0
1
2
3
4
5
6
Brucella anthracis
Diplococcus pneumoniae
Staphylococcus albus
Staphylococcus aureus
Streptococcus fecalis
Streptococcus hemolyticus
Streptococcus viridans
Aerobacter aerogenes
Brucella abortus
Escherichia coli
Klebsiella pneumoniae
Mycobacterium tuberculosis
Proteus vulgaris
Pseudomonas aeruginosa
Salmonella (Eberthella) typhosa
Salmonella schottmuelleri
the higher, the more effective
Effectiveness = lg(1/MIC)+3
Antibiotic
Neomycin
Penicilin
Streptomycin

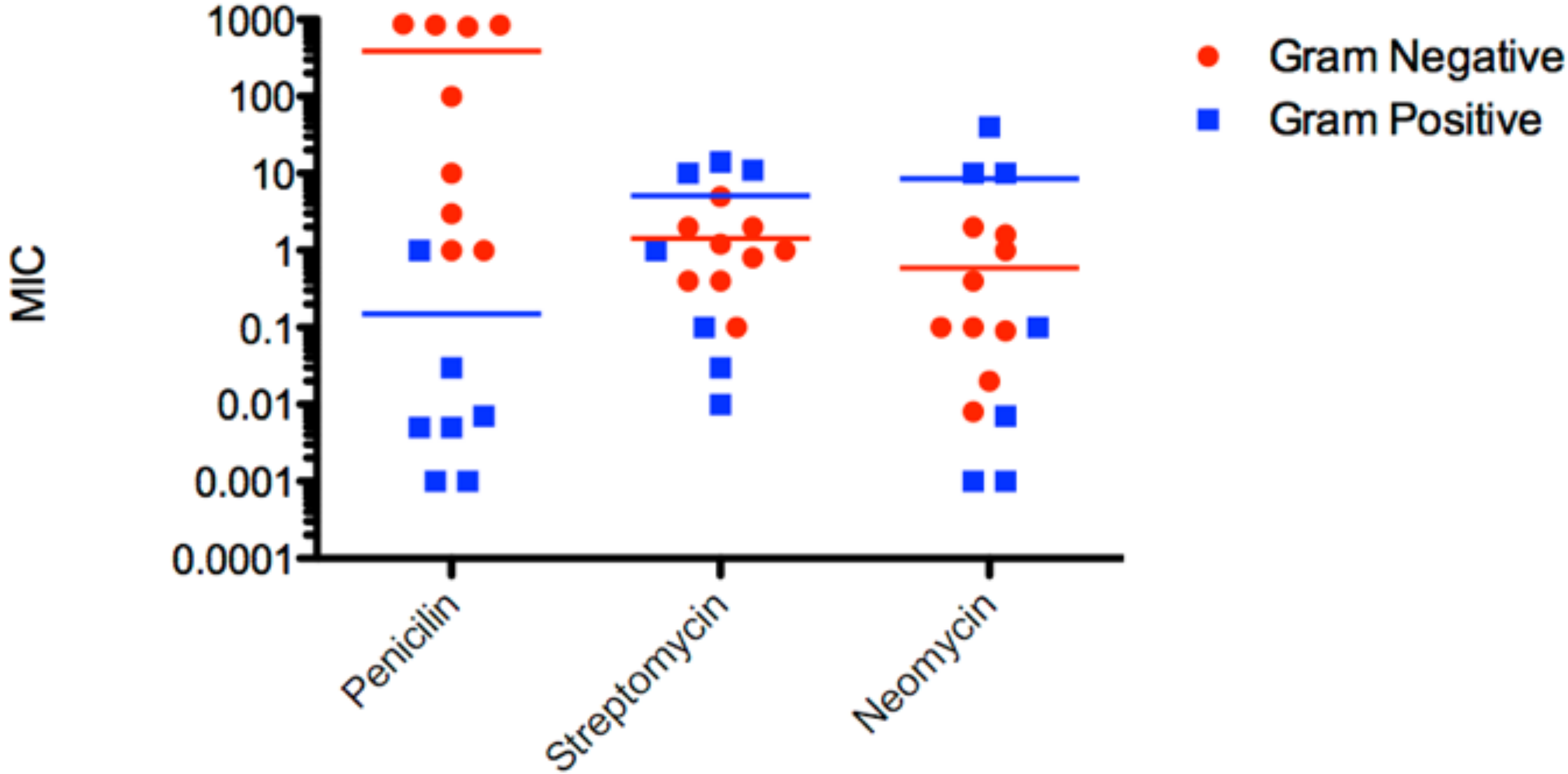
Comparing the effect of antibiotics by their minimum inhibitory concentration for 16 bacteria (Burtin's data, 1951)



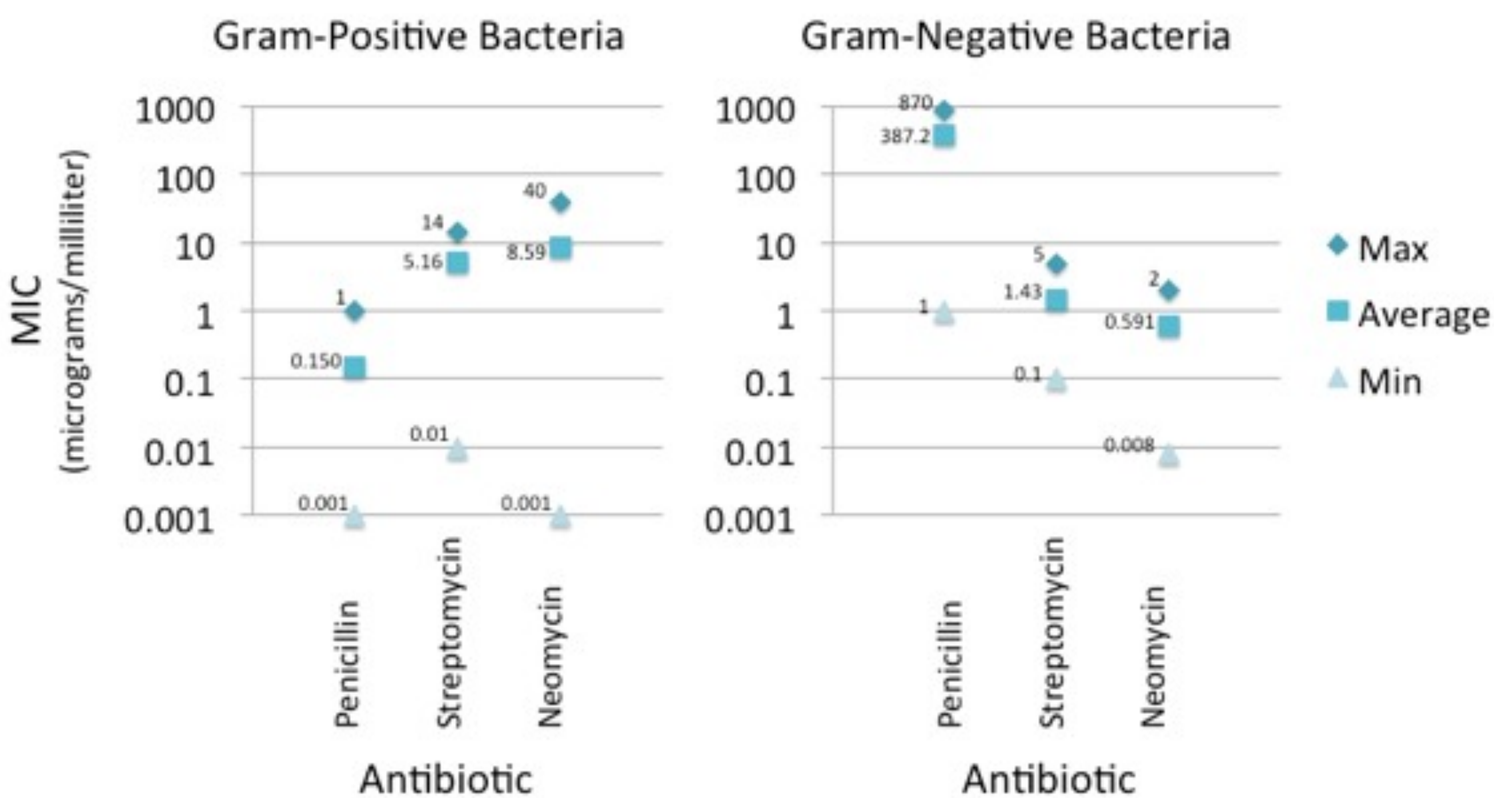
Effectiveness of Antibiotics
tested on sixteen different strains of bacteria
minimum inhibitory concentration (µg / mL)
of antibiotic required to prevent growth of bacteria
1000
100
10
1
0.1
0.01
0.001
Penicilin
Streptomycin
Neomycin
single strain of
gram-negative bacteria
single strain of
gram-positive bacteria
range
mean effectiveness of
antibiotic on group of
gram-stained bacteria

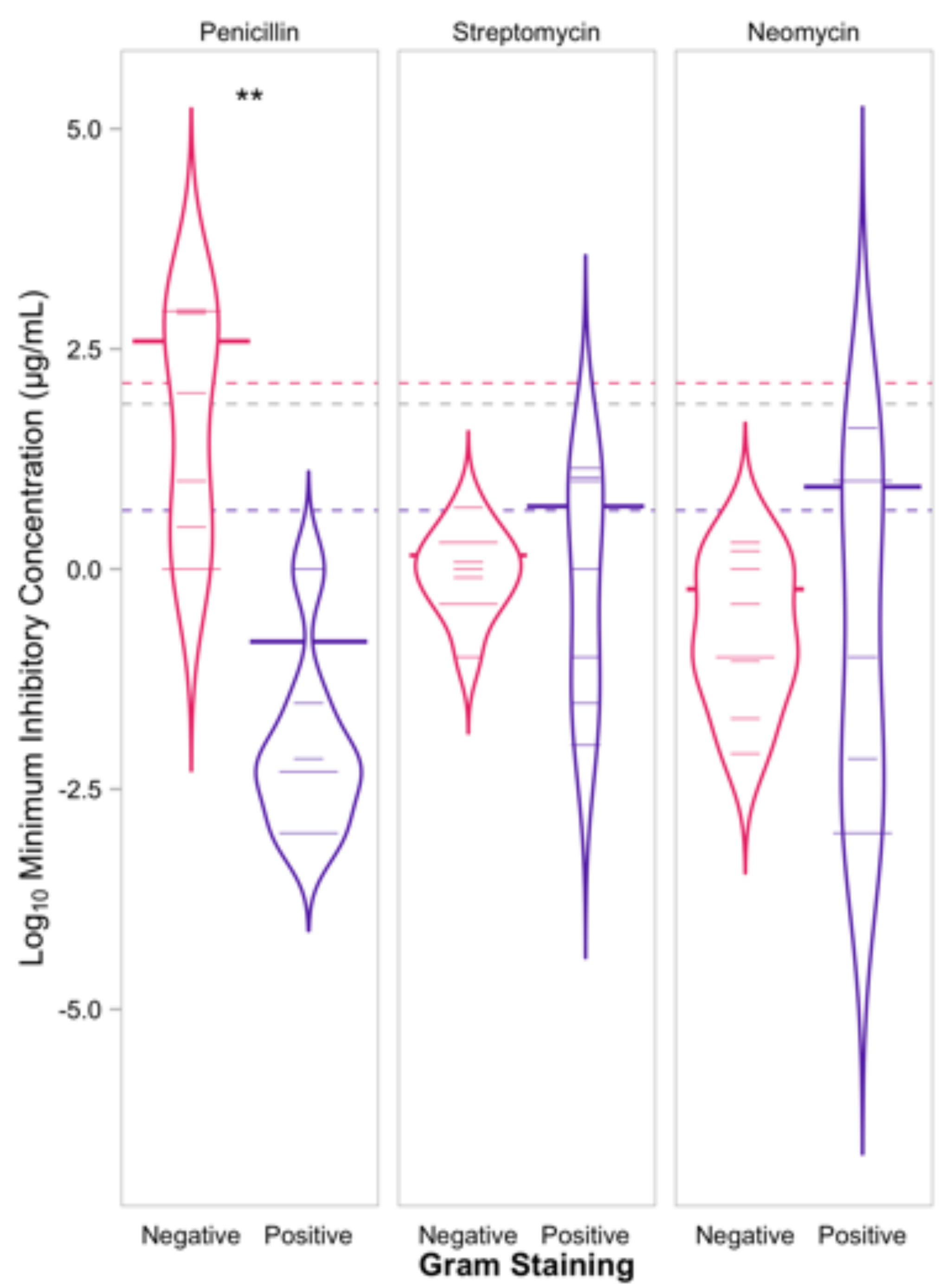

Antibiotic concentrations required to inhibit selected bacteria
gram positive species
gram negative species
Neomycin
Streptomycin
Penicillin
0.001
0.01
0.1
1
10
100
1000
<-- more effective
Minimum Inhibitory Concentration
less effective -->

Correlationship between Gram staining and antibiotics



Minimum Inhibitory Concentration (MIC) for Antibiotics to Inhibit Bacteria Growth




Penicillin
Streptomycin
Neomycin
**
5.0
2.5
0.0
-2.5
-5.0
Log10 Minimum Inhibitory Concentration (µg/mL)
Negative
Positive
Negative
Positive
Negative
Positive
Gram Staining

Tables / Heat Maps

Which Antibiotic Is Most Effective For Which Bacteria?

		Antibiotic	
Bacteria	Penicillin	Streptomycin	Neomycin
Aerobacter aerogenes	870	1	1.6
Brucella abortus	1	2	0.02
Brucella anthracis	0.001	0.01	0.007
Diplococcus pneumoniae	0.005	11	10
Escherichia coli	100	0.4	0.1
Klebsiella pneumoniae	850	1.2	1
Myobacterium tuberculosis	800	5	2
Proteus vulgaris	3	0.1	0.1
Pseudomonas aerouginosa	850	2	0.4
Salmonella (Eberthella) typhosa	1	0.4	0.008
Salmonella schottmuelleri	10	0.8	0.09
Staphylococcus albus	0.007	0.1	0.001
Staphylococcus aureus	0.03	0.03	0.001
Streptococcus fecalis	1	1	0.1
Streptococcus hemolyticus	0.001	14	10
Streptococcus viridans	0.005	10	40

Values in the table indicate the minimum inhibitory concentration measured for an antibiotic. The smallest values for each bacteria are highlighted.

Minimum Inhibitory Concentration (MIC) of antibiotics required to prevent growth of bacteria

Bacteria	Gram	Penicilin	Streptomycin	Neomycin
Streptococcus hemolyticus	Gram-Positive	0.001	14	10
Streptococcus viridans	Gram-Positive	0.005	10	40
Diplococcus pneumoniae	Gram-Positive	0.005	11	10
Staphylococcus albus	Gram-Positive	0.007	0.1	0.001
Staphylococcus aureus	Gram-Positive	0.03	0.03	0.001
Brucella anthracis	Gram-Positive	0.001	0.01	0.007
Streptococcus fecalis	Gram-Positive	1	1	0.1
Proteus vulgaris	Gram-Positive	3	0.1	0.1
Brucella abortus	Gram-Positive	1	2	0.02
Salmonella schottmuelleri	Gram-Negative	10	0.8	0.09
Salmonella (Eberthella) typhosa	Gram-Negative	1	0.4	0.008
Mycobacterium tuberculosis	Gram-Negative	800	5	2
Klebsiella pneumoniae	Gram-Negative	850	1.2	1
Aerobacter aerogenes	Gram-Negative	870	1	1.6
Escherichia coli	Gram-Negative	100	0.4	0.1
Pseudomonas aeruginosa	Gram-Negative	850	2	0.4

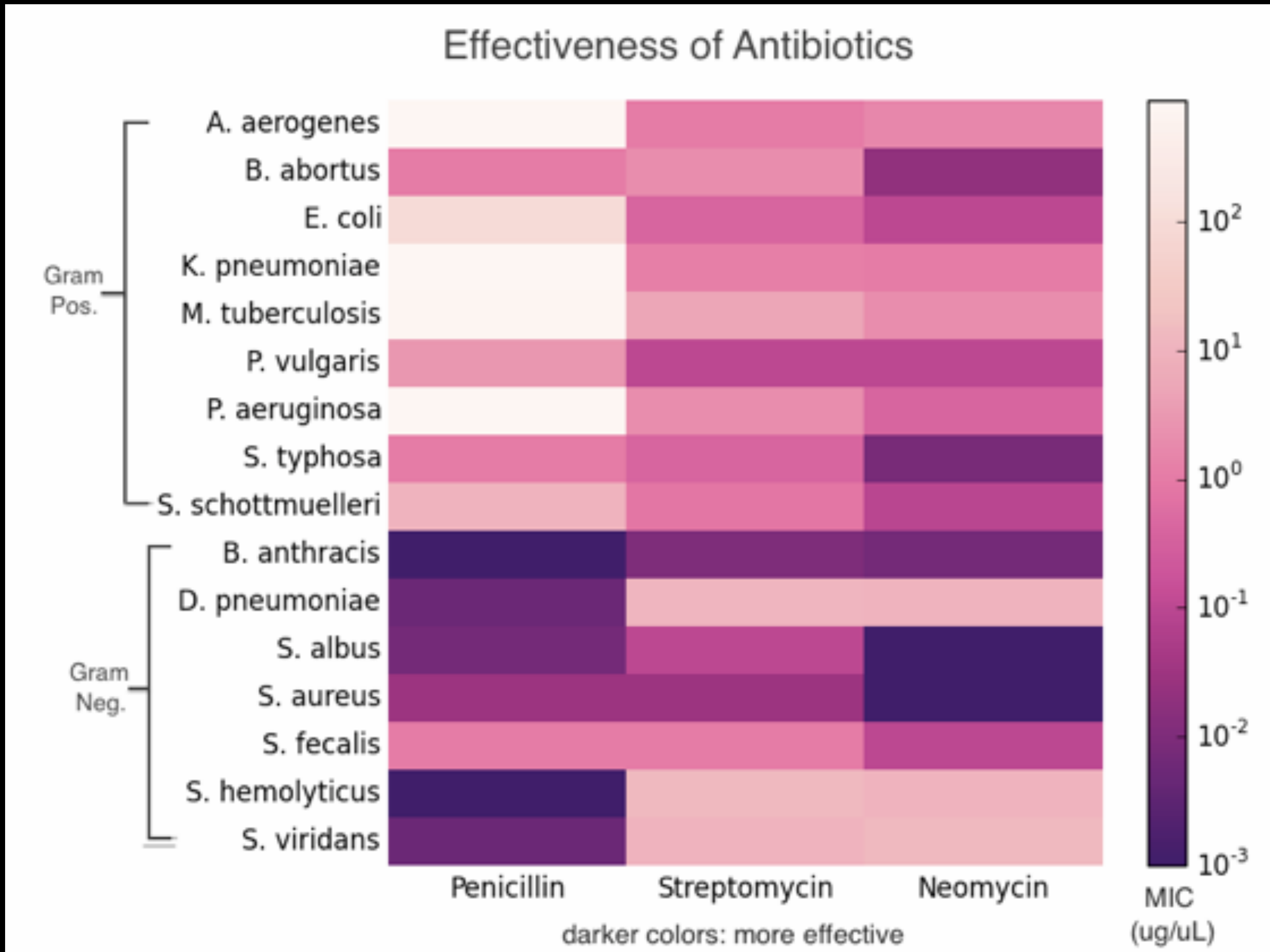
MIC for Antibiotic

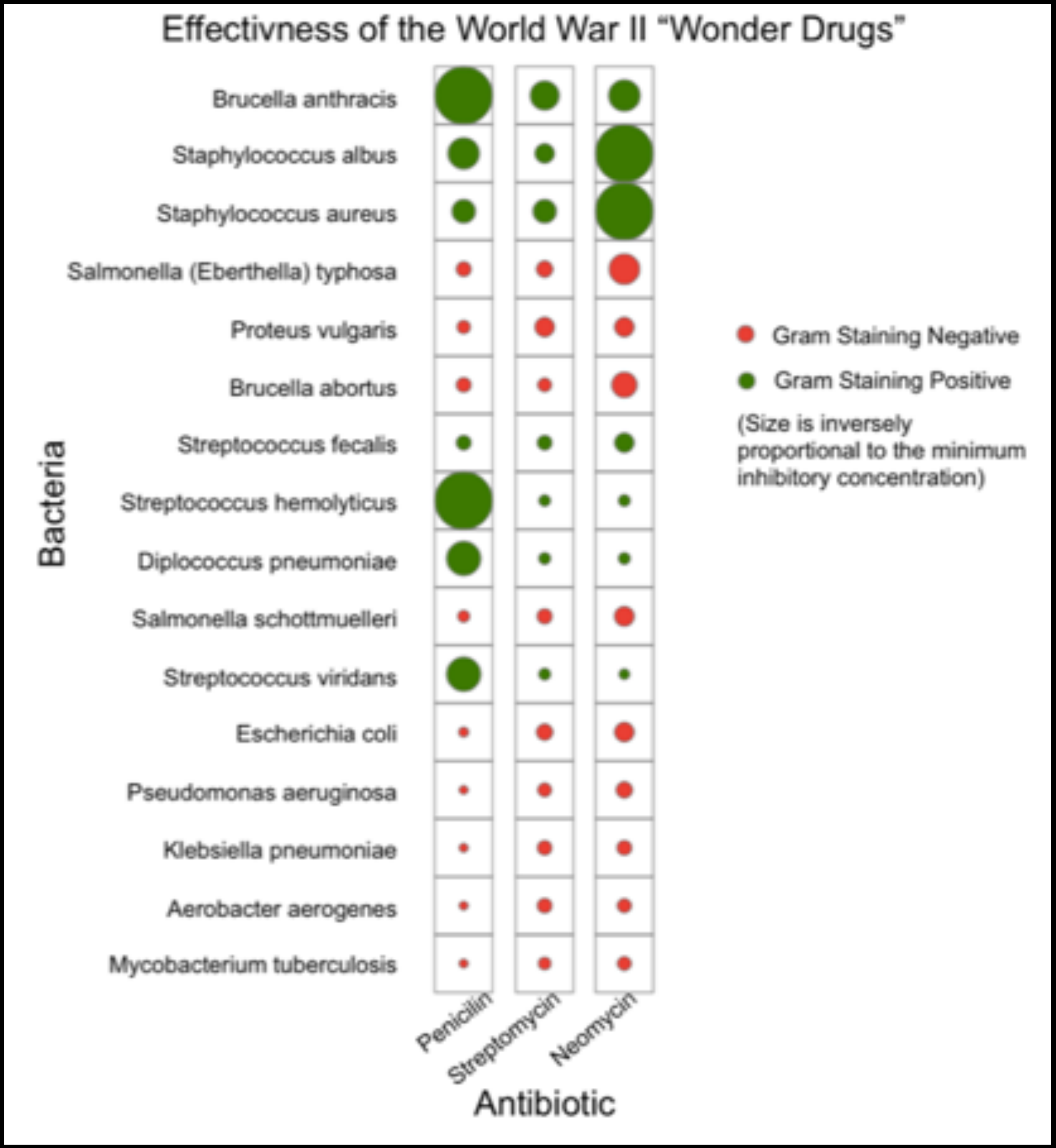
Bacterial Resistance to Antibiotics

Bacteria	Gram Staining	Antibiotics		
		Penicilin	Streptomycin	Neomycin
Aerobacter aerogenes	negative			
Brucella abortus	negative			
Brucella anthracis	positive			
Diplococcus pneumoniae	positive			
Escherichia coli	negative			
Klebsiella pneumoniae	negative			
Mycobacterium tuberculosis	negative			
Proteus vulgaris	negative			
Pseudomonas aeruginosa	negative			
Salmonella (Eberthella) typhosa	negative			
Salmonella schottmuelleri	negative			
Staphylococcus albus	positive			
Staphylococcus aureus	positive			
Streptococcus fecalis	positive			
Streptococcus hemolyticus	positive			
Streptococcus viridans	positive			

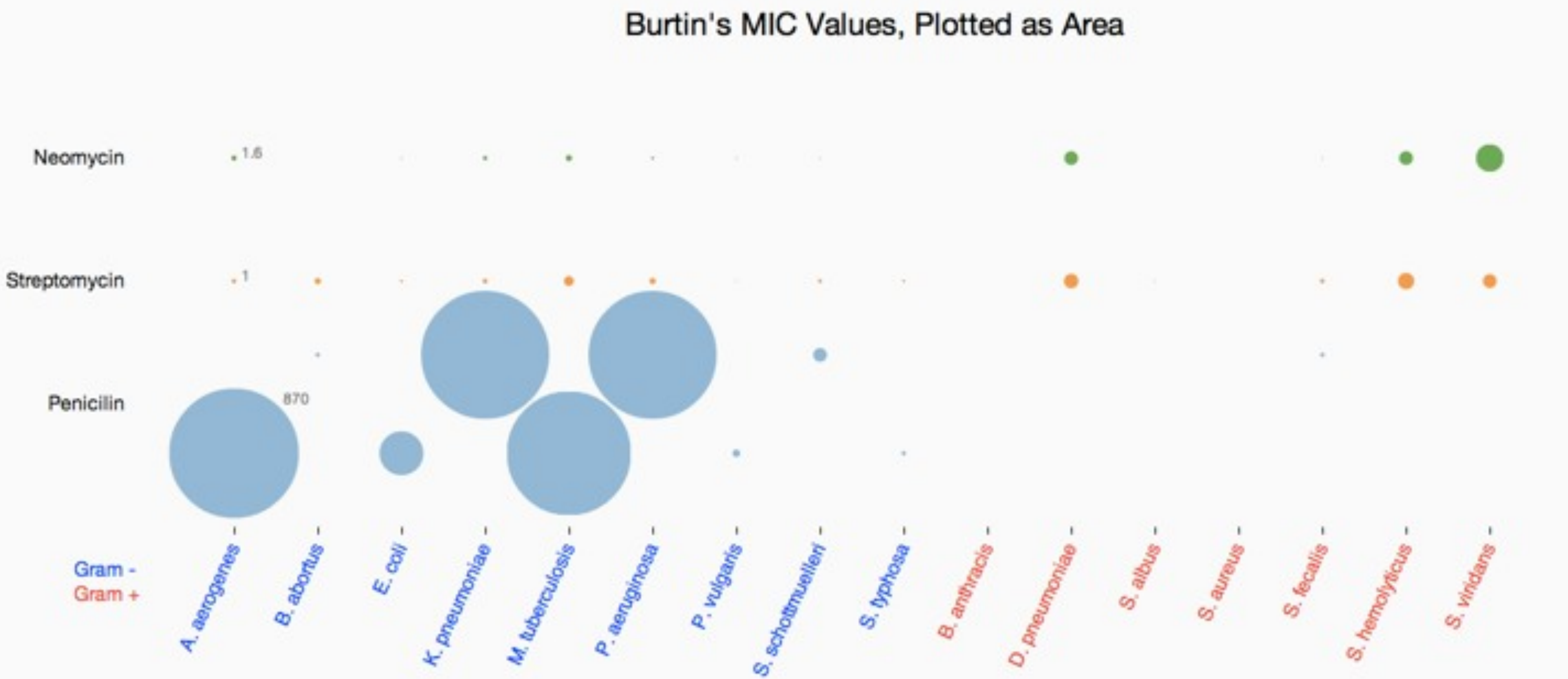
0.001	0.01	0.1	1	10	100	870

minimum inhibitory concentration (μg/L)


Effectiveness of Antibiotics
A. aerogenes
B. abortus
E. coli
K. pneumoniae
M. tuberculosis
P. vulgaris
P. aeruginosa
S. typhosa
S. schottmuelleri
B. anthracis
D. pneumoniae
S. albus
S. aureus
S. fecalis
S. hemolyticus
S. viridans
Gram Pos.
Gram Neg.
Penicillin
Streptomycin
Neomycin
darker colors: more effective
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
MIC (ug/uL)


Effectivness of the World War II "Wonder Drugs"
Bacteria
Brucella anthracis
Staphylococcus albus
Staphylococcus aureus
Salmonella (Eberthella) typhosa
Proteus vulgaris
Brucella abortus
Streptococcus fecalis
Streptococcus hemolyticus
Diplococcus pneumoniae
Salmonella schottmuelleri
Streptococcus viridans
Escherichia coli
Pseudomonas aeruginosa
Klebsiella pneumoniae
Aerobacter aerogenes
Mycobacterium tuberculosis
Penicilin
Streptomycin
Neomycin
Antibiotic
Gram Staining Negative
Gram Staining Positive
(Size is inversely proportional to the minimum inhibitory concentration)

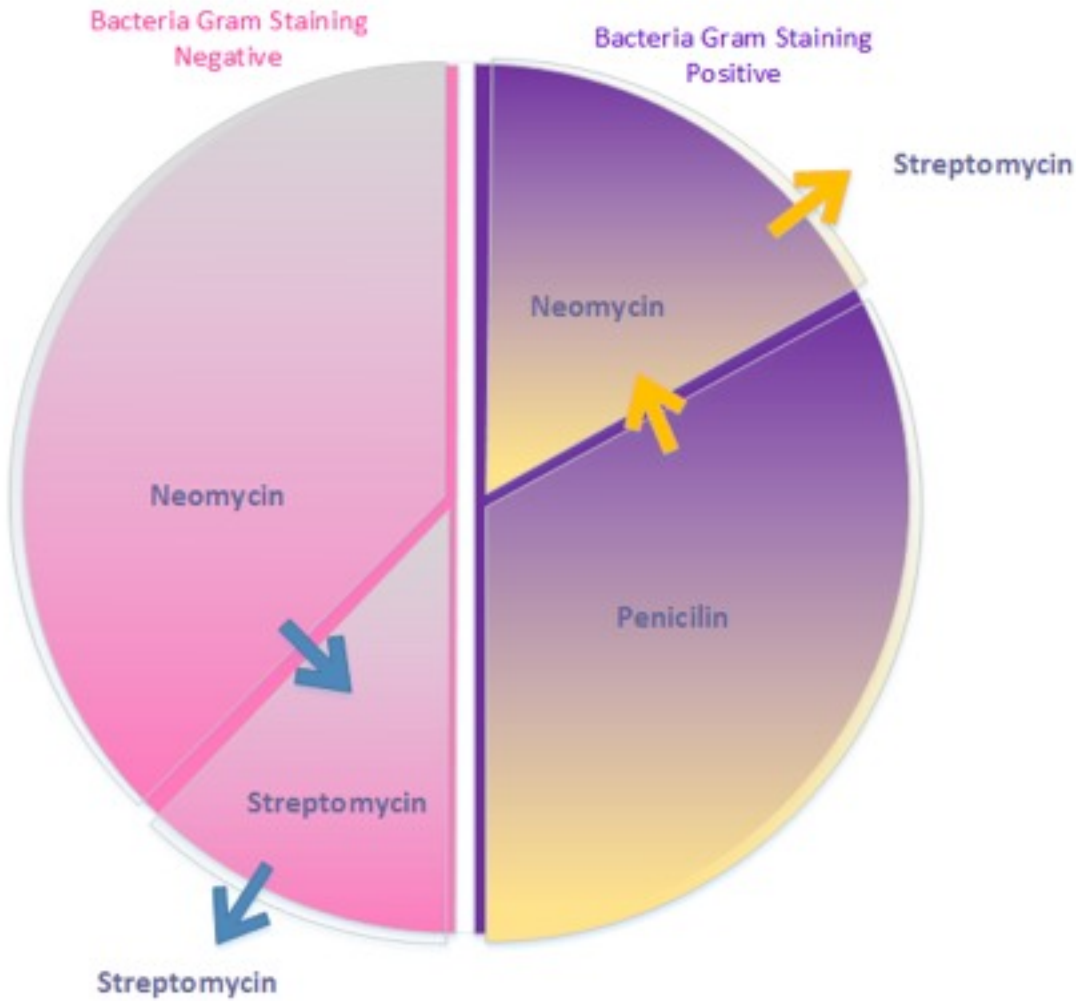

Bacteria
Penicilin
Streptomycin
Neomycin
Aerobacter aerogenes
870
1
1.6
Klebsiella pneumoniae
850
1.2
1
Pseudomonas aeruginosa
850
2
0.4
Mycobacterium tuberculosis
800
5
2
Escherichia coli
100
0.4
0.1
Proteus vulgaris
3
0.1
0.1
Salmonella schottmuelleri
10
0.8
0.09
Brucella abortus
1
2
0.02
Salmonella (Eberthella) typhosa
1
0.4
0.008
Streptococcus fecalis
1
1
0.1
Diplococcus pneumoniae
0.005
11
10
Streptococcus hemolyticus
0.001
14
10
Streptococcus viridans
0.005
10
40
Brucella anthracis
0.001
0.01
0.007
Staphylococcus albus
0.007
0.1
0.001
Staphylococcus aureus
0.03
0.03
0.001
Gram Staining
Negative
Positive
Minimum Inhibitory Concentration (MIC)
0.001
0.01
0.1
1
10
100
1000
Effective
Ineffective



Burtin's MIC Values, Plotted as Area
Neomycin
Streptomycin
Penicilin
1.6
1
870
Gram -
Gram +
A. aerogenes
B. abortus
E. coli
K. pneumoniae
M. tuberculosis
P. aeruginosa
P. vulgaris
S. schottmuelleri
S. typhosa
B. anthracis
D. pneumoniae
S. albus
S. aureus
S. fecalis
S. hemolyticus
S. viridans

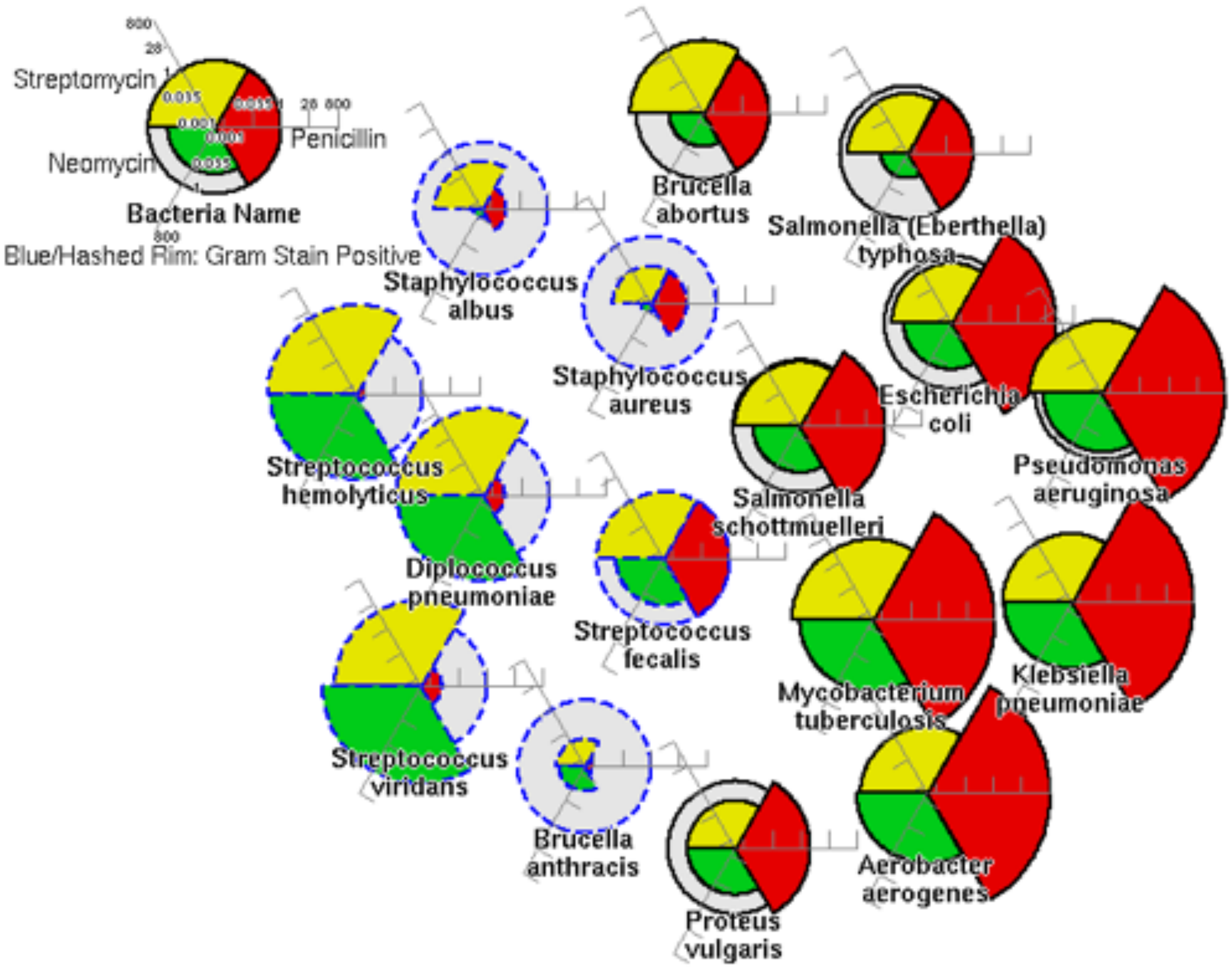
Other

What Antibiotics to Use

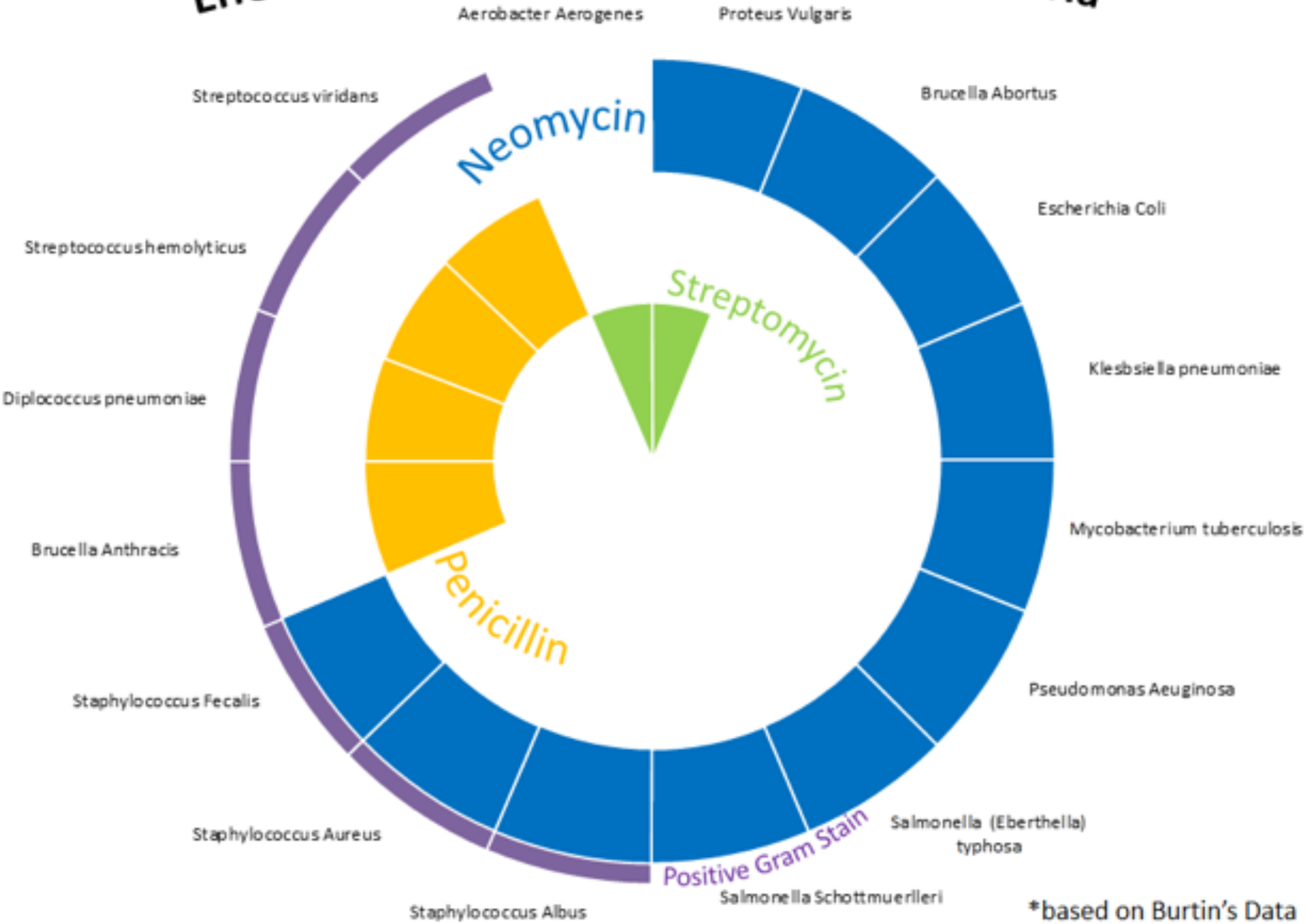


Dosage Needed to Combat Bacteria

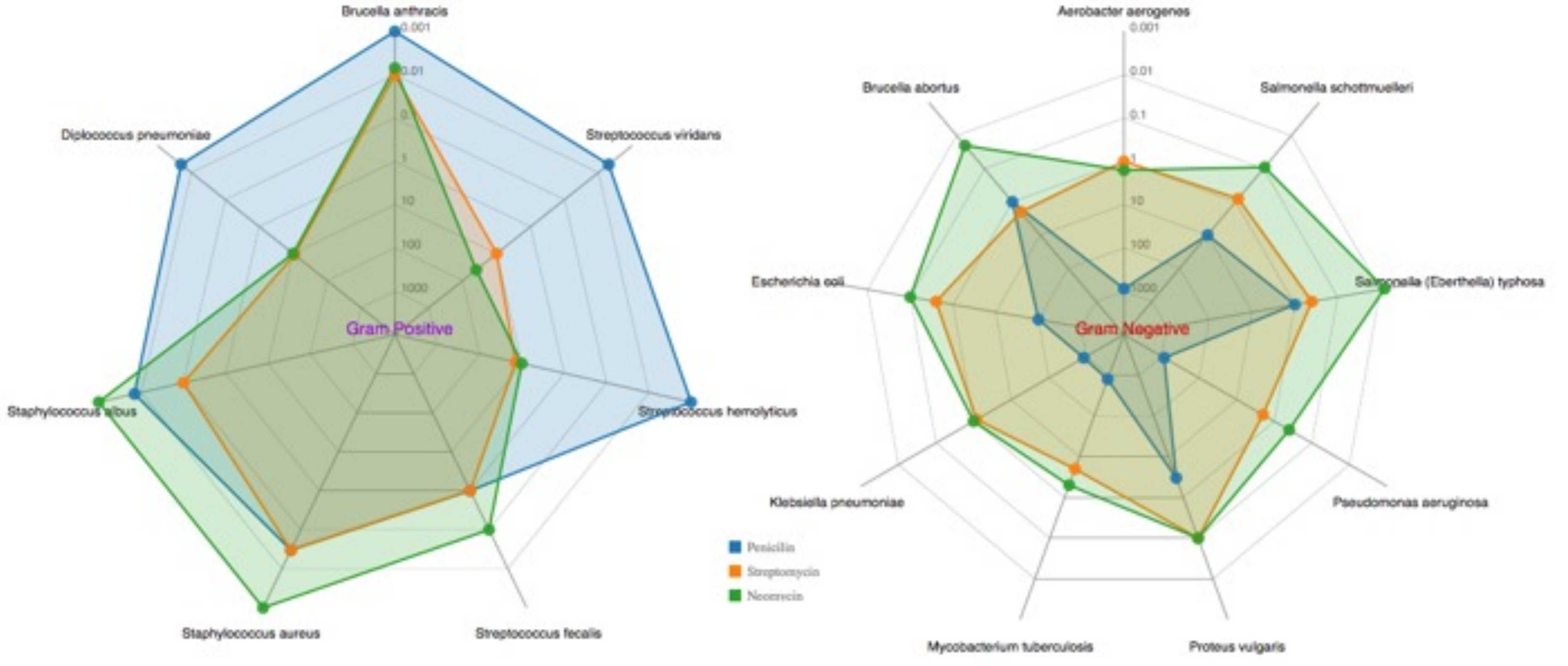
Size of wedge shows amount of an antibiotic needed to suppress bacterial growth
As Minimum Inhibitory Concentration (MIC), plotted on a log scale



Effective Antibiotics Against Various Bacteria*

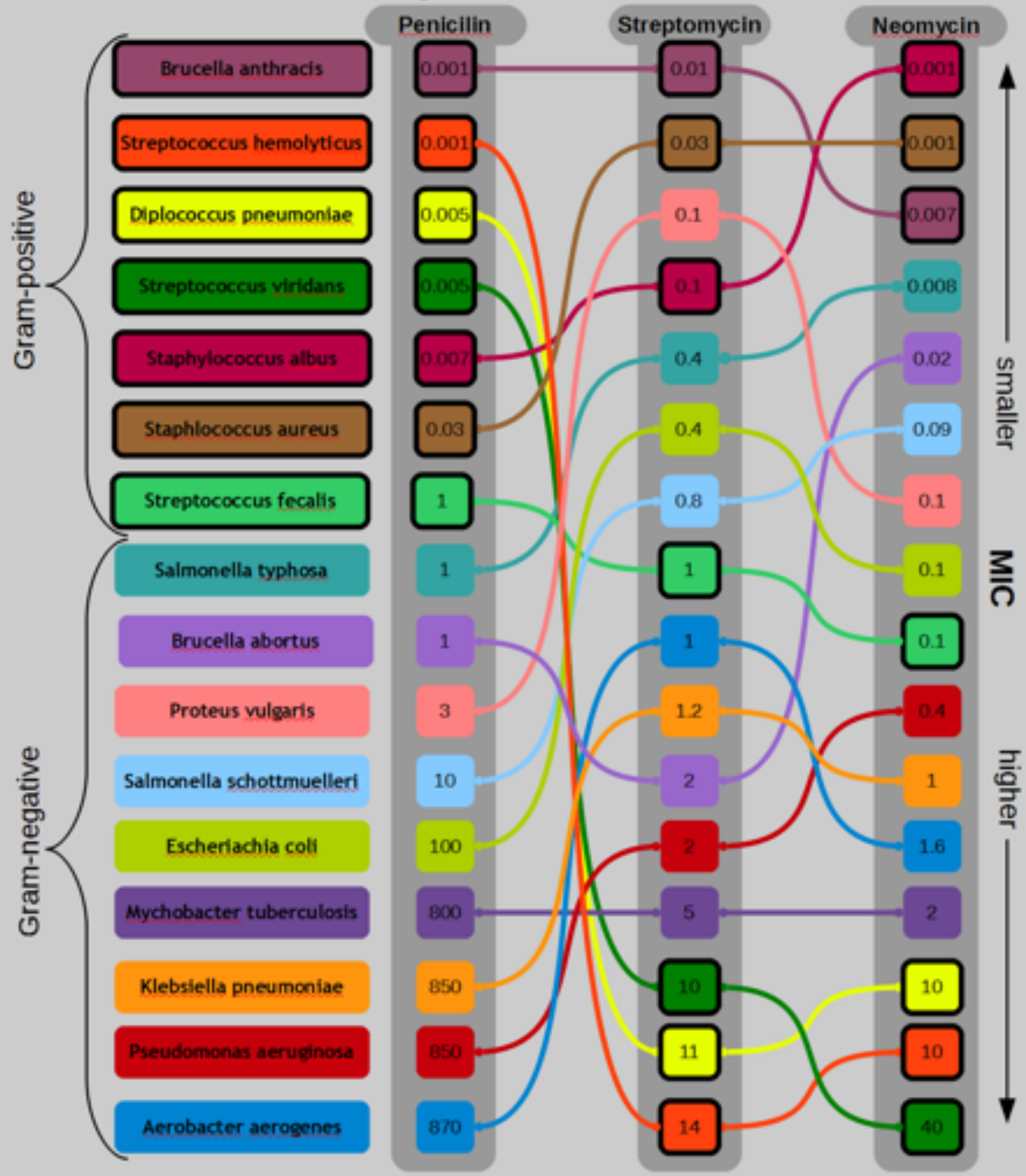


*based on Burtin's Data

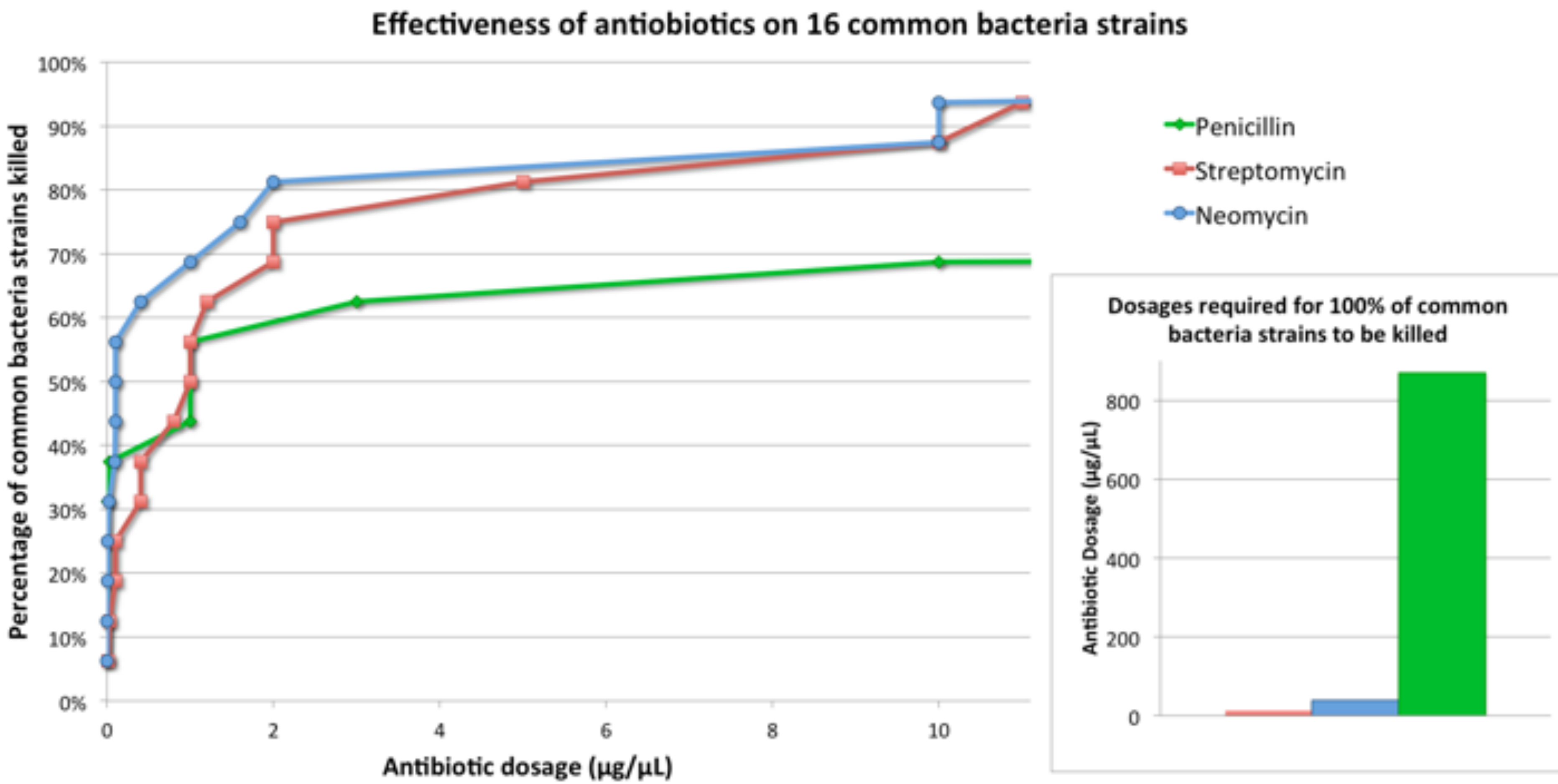


Minimum inhibitory concentration of Antibiotics

Minimum Inhibitory Concentration for Three Antibiotics

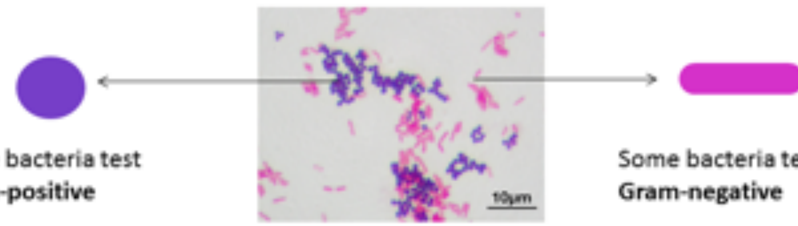


Effectiveness of Antibiotics against Bacteria


Effectiveness of antiobiotics on 16 common bacteria strains
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of common bacteria strains killed
0
2
4
6
8
10
Antibiotic dosage (μg/μL)
Penicillin
Streptomycin
Neomycin
Dosages required for 100% of common bacteria strains to be killed
Antibiotic Dosage (μg/μL)
800
600
400
200
0

Which antibiotic should I take?

Even if you know you have a bacterial infection, it's hard to tell what kind. You need to know that to know which antibiotic is most effective. Your doctor can use the **"Gram" stain test** and **look** at the bacteria:



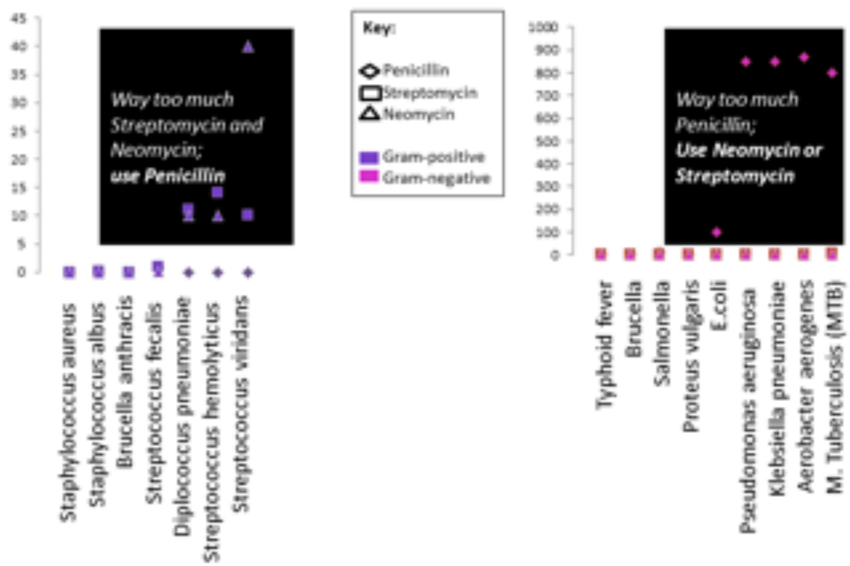
Some bacteria test **Gram-positive**

Some bacteria test **Gram-negative**

Some antibiotics work well for some bacteria and some don't.

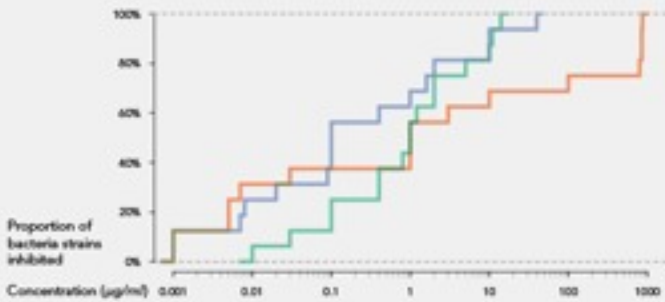
For example, to kill **Tuberculosis** bacteria, you would need to use a *lot* (400 times!) more Penicillin than Neomycin. Antibiotics are blind: they kill many organisms in your body, not just the bad bacteria. So, it would be much better for your body to use Neomycin, and it would still work. Some of the **Gram-negative** bacteria need a lot more Penicillin, **so Streptomycin and Neomycin** is better.

How much antibiotics need to be applied to kill **different kinds of bacteria**?



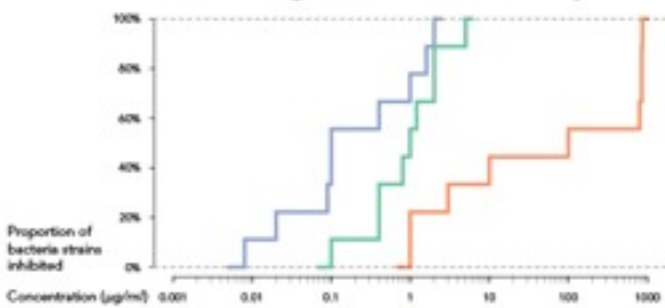
Dose efficiency of three antibiotics against —

All bacteria



Streptomycin and Neomycin are more efficient broad-spectrum antibiotics than Penicilin.

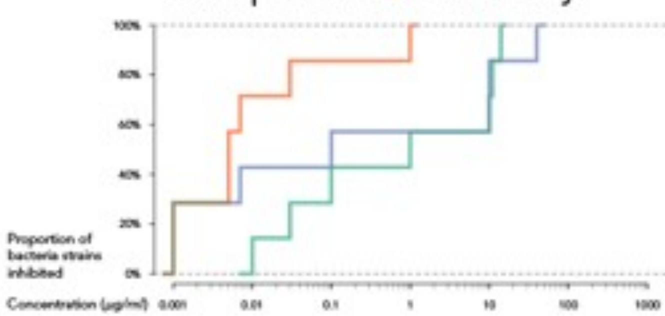
Gram-negative bacteria only



Neomycin and Streptomycin are more efficient against gram-negative bacteria, so can be used at a lower dosage here than above.

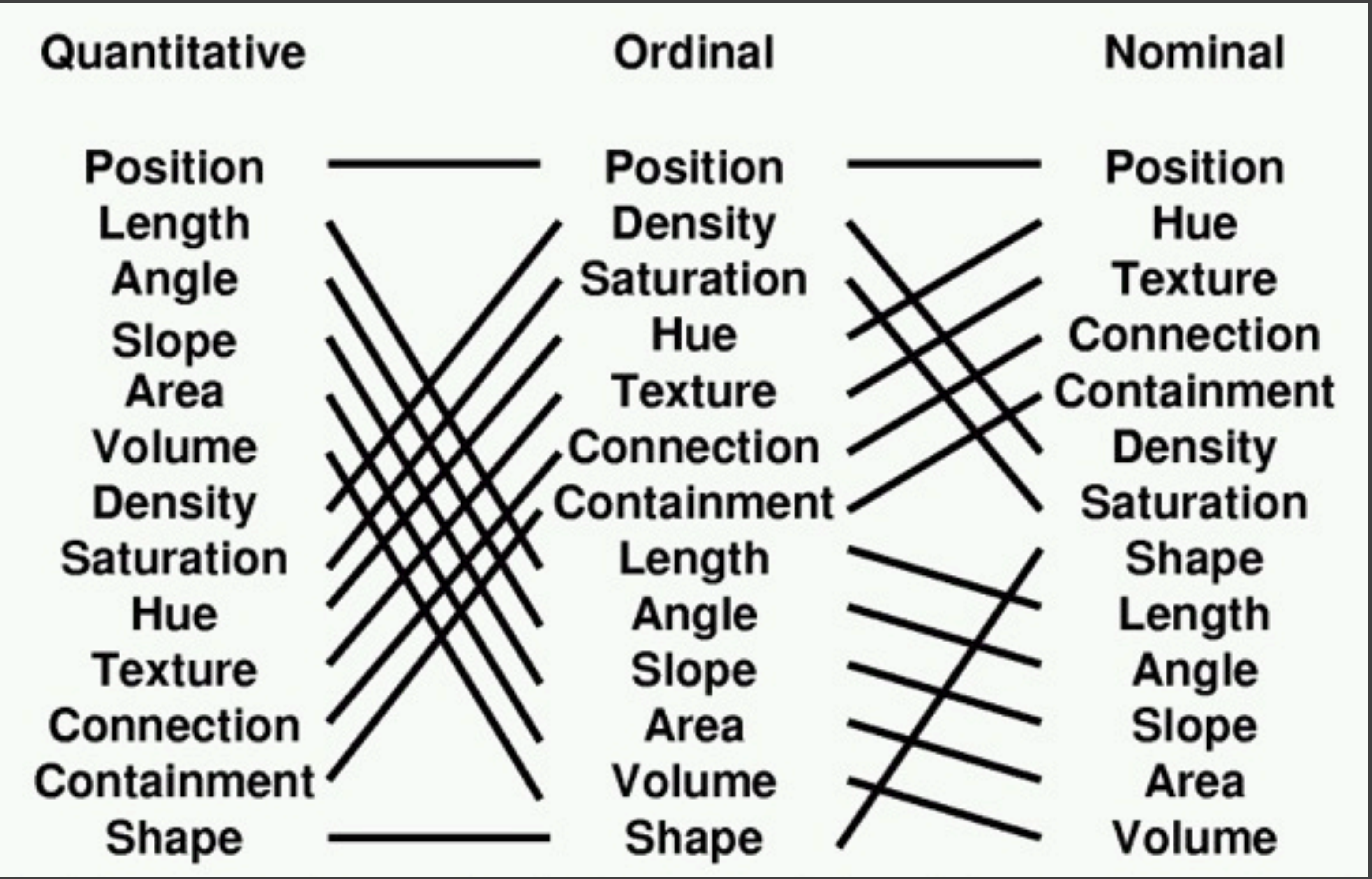
Gram staining quickly identifies bacteria as **Gram-negative** or **Gram-positive**, which can be used to find a more efficient antibiotic and dosage.

Gram-positive bacteria only

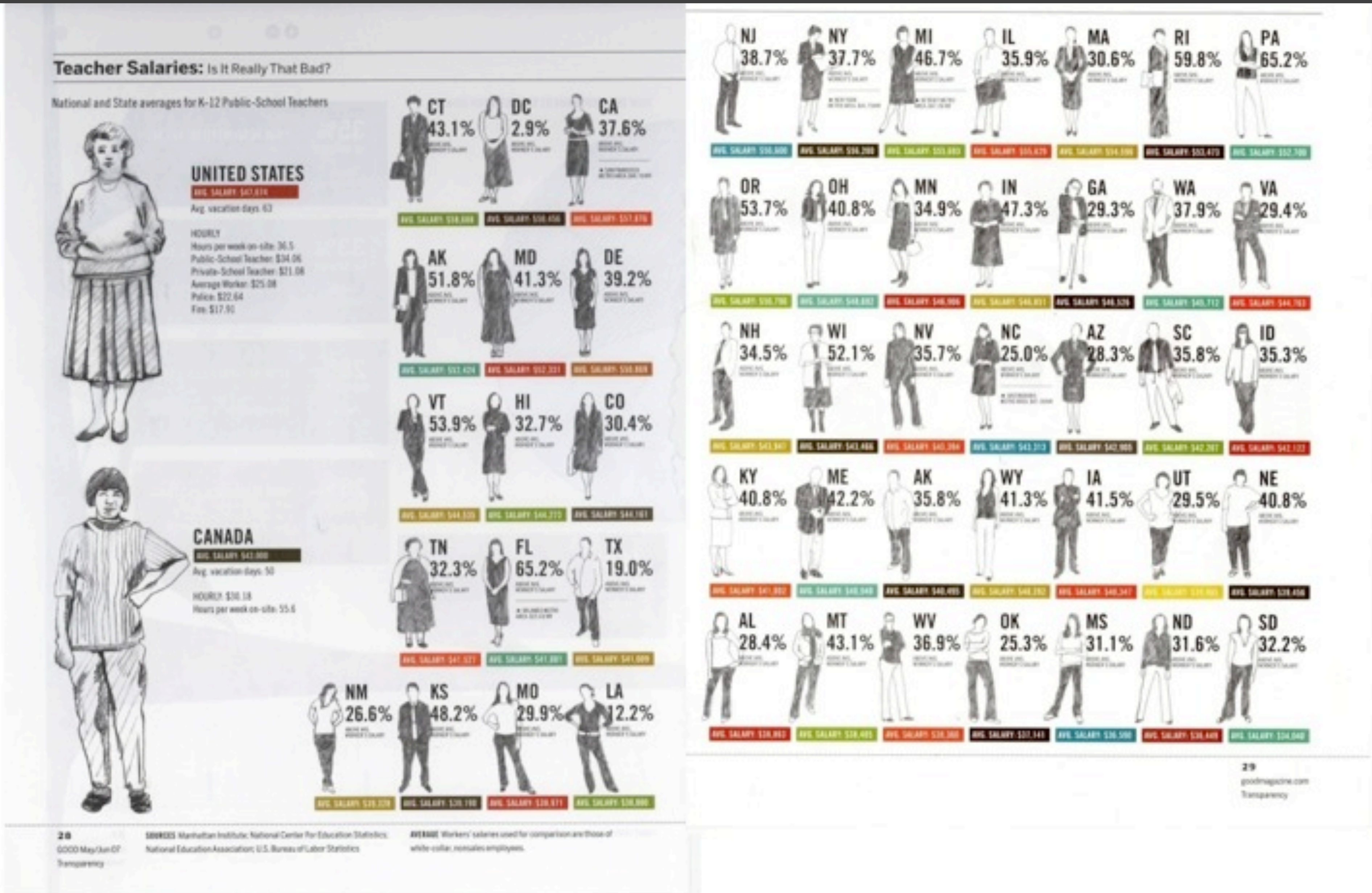


Penicilin is more efficient than either Streptomycin or Neomycin if the bacteria is known to be gram-positive.

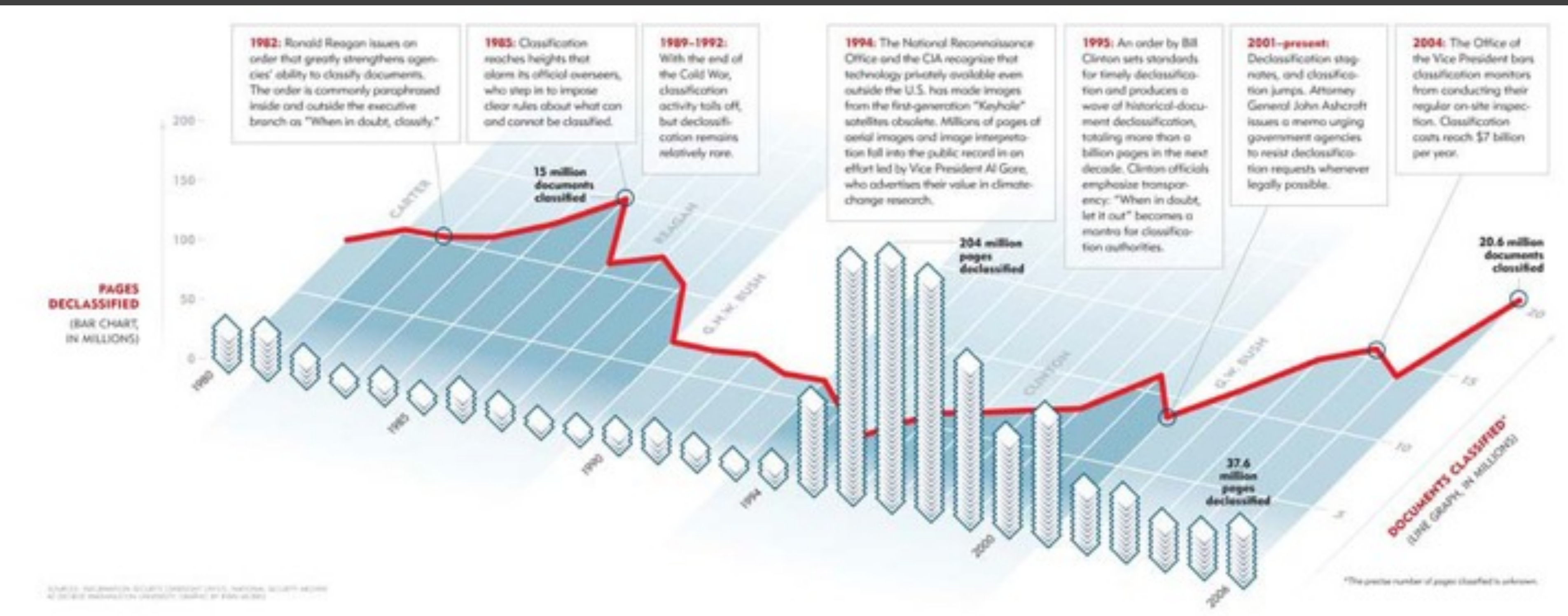
Mackinlay's Ranking



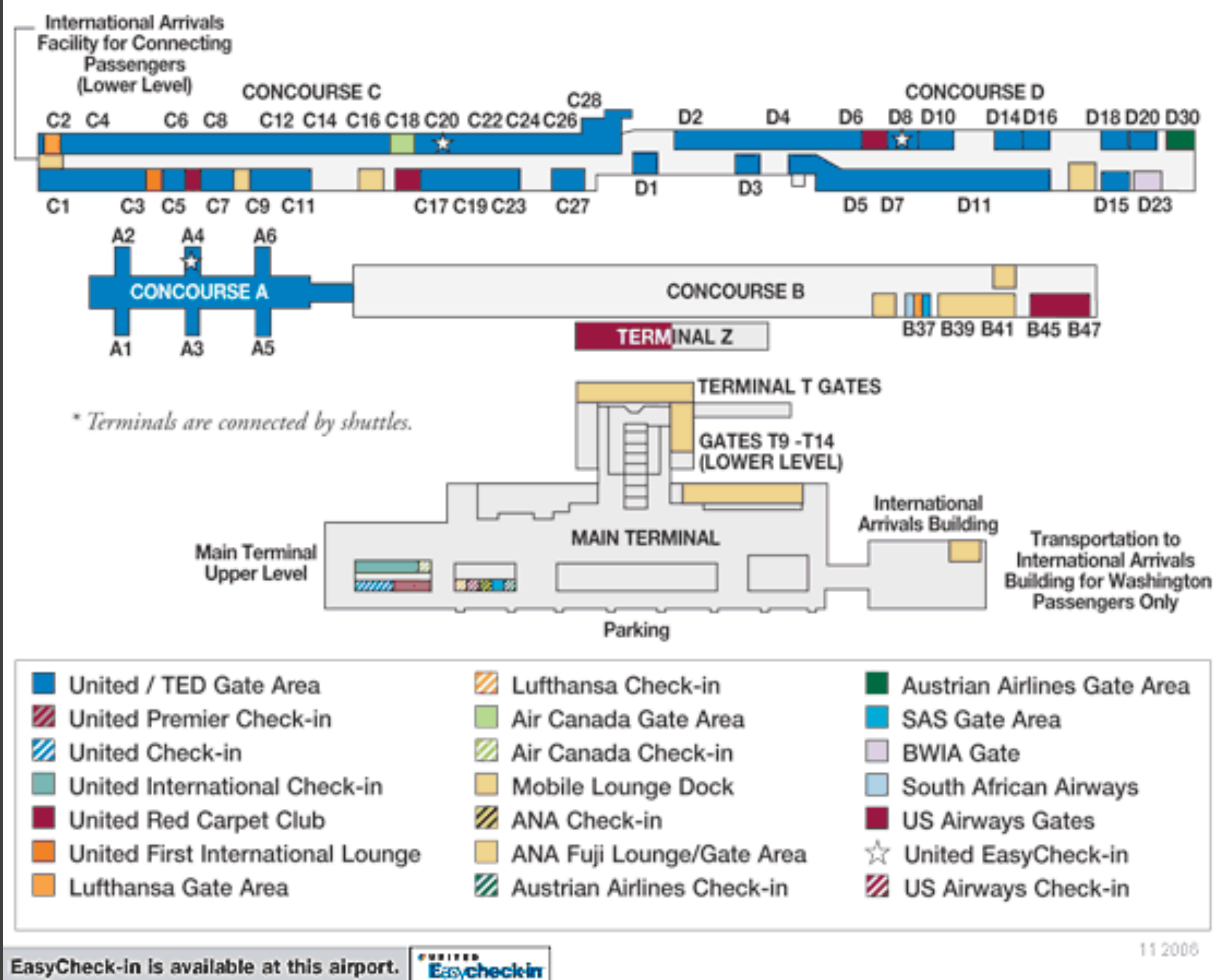
Conjectured *effectiveness* of the encoding



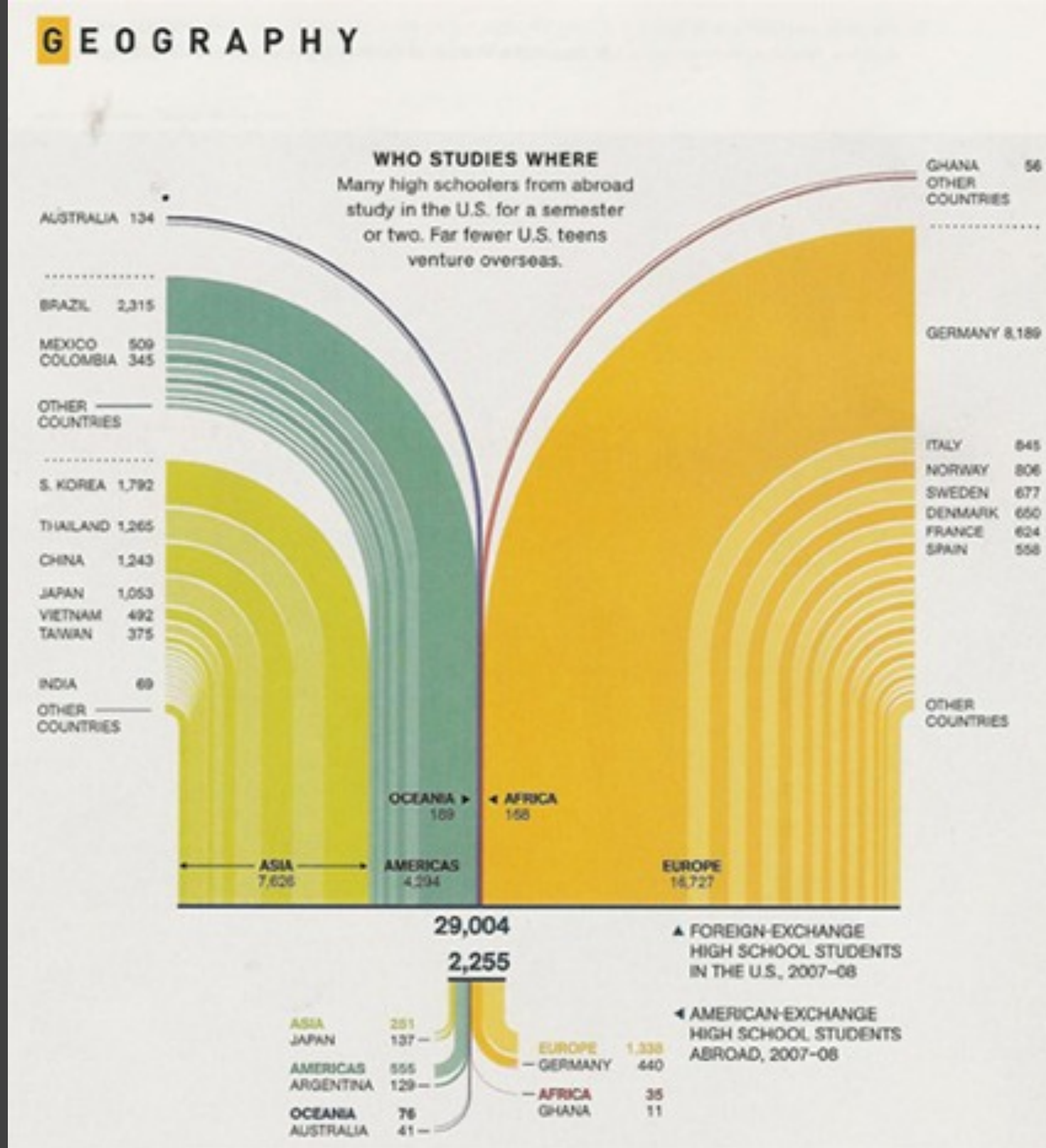
Source: *Good* Magazine



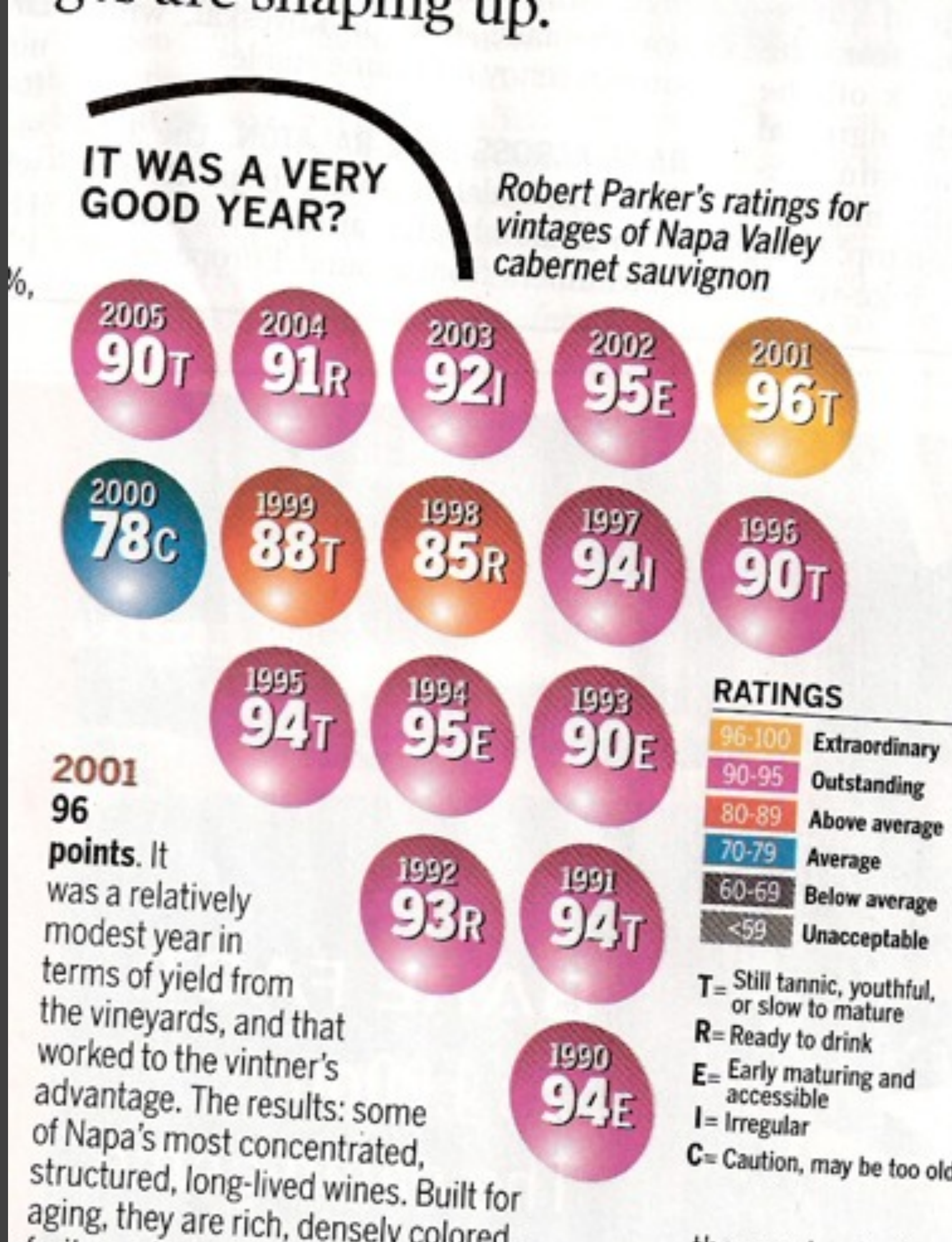
Source: *The Atlantic* 300 no. 2 (September 2007)
Number of Classified U.S. Documents



Washington Dulles Airport Map
Source: United Airlines *Hemispheres*



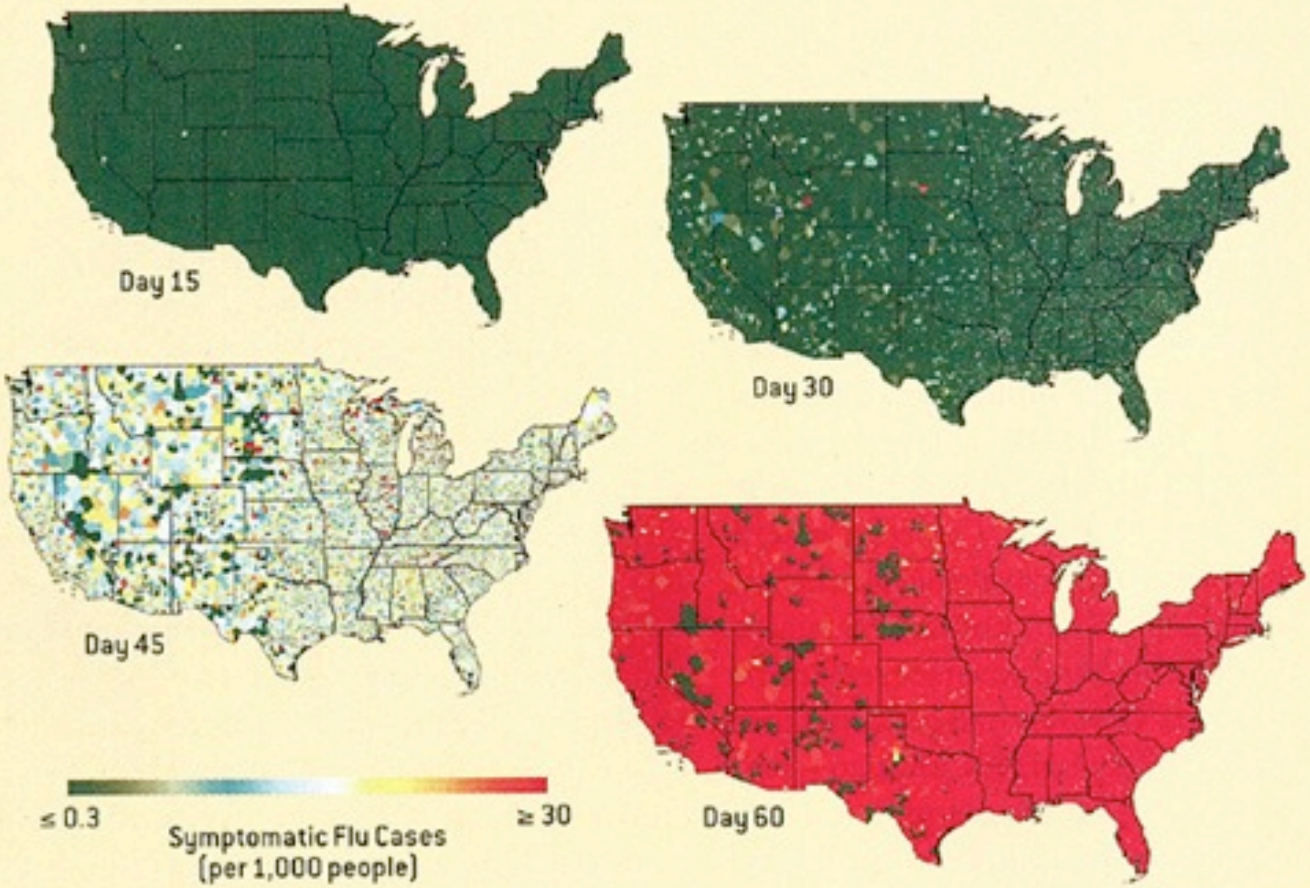
Source: *National Geographic*, September, 2008, p. 22. Silver, Mark. "High School Give-and-Take."



Source: *Business* Week, June 18, 2007

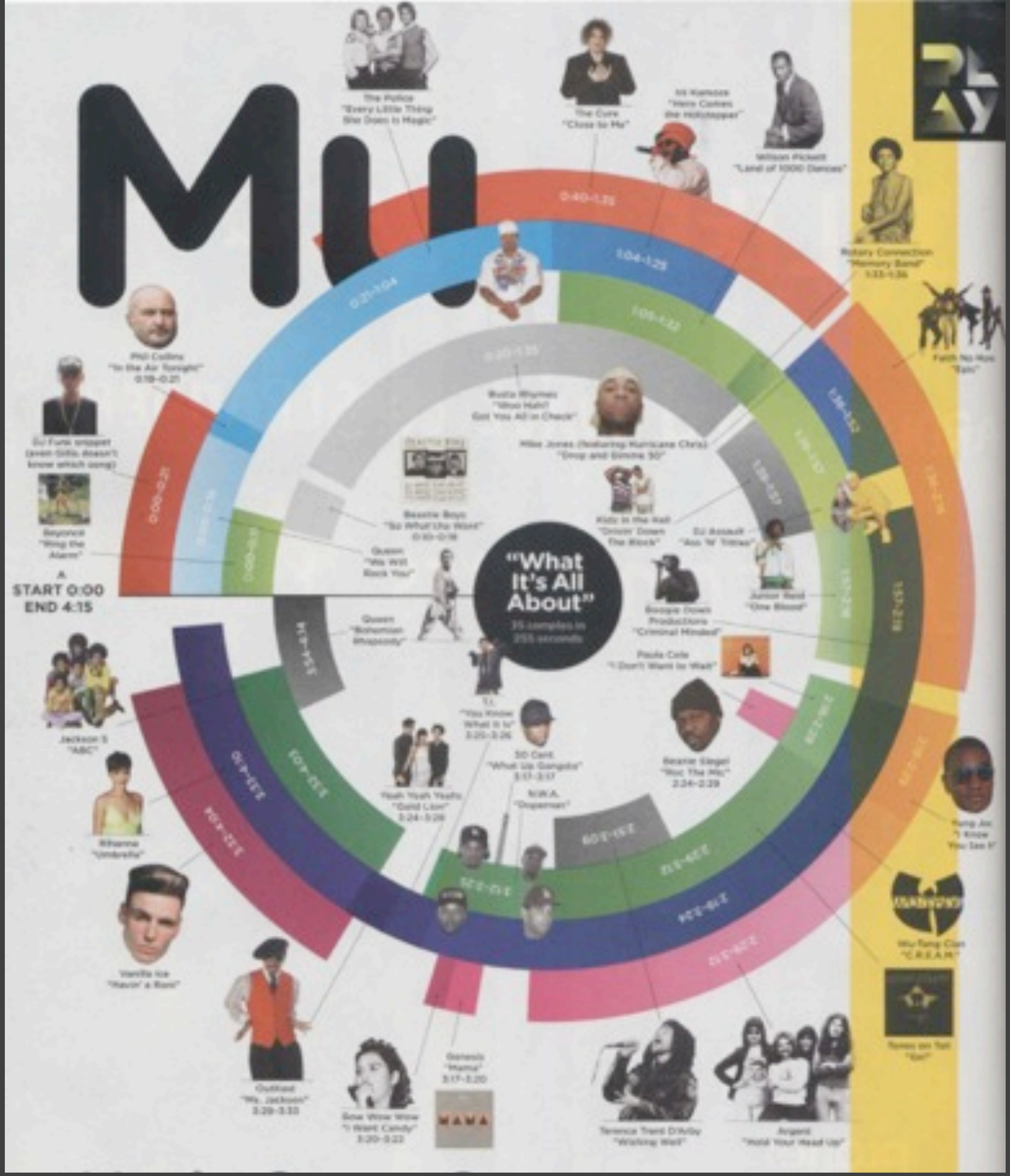
Pandemic Flu Hits the U.S.

A simulation created by researchers from Los Alamos National Laboratory and Emory University shows the first wave of a pandemic spreading rapidly with no vaccine or antiviral drugs employed to slow it down. Colors represent the number of symptomatic flu cases per 1,000 people [*see scale*]. Starting with 40 infected people on the first day, nationwide cases peak around day 60, and the wave subsides after four months with 33 percent of the population having become sick. The scientists are also modeling potential interventions with drugs and vaccines to learn if travel restrictions, quarantines and other disruptive disease-control strategies could be avoided.



Preparing for a Pandemic

Source: *Scientific American*, 293(5). November, 2005, p. 50



Source: *Wired Magazine*, September 2008 Edition
Music: Super Cuts (page 92)