

Assess pairwise growth data

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load in data

Pairwise data assessment

Are data normally distributed? – run shapiro tests

```
## [1] "135E under condition alone at pH 5 on day 3 is not normal, with p value 0.00555699432678654"
## [1] "135E under condition alone at pH 5 on day 10 is not normal, with p value 0.00262074320444773"
## [1] "135E under condition alone at pH 7 on day 21 is not normal, with p value 0.00550426107538683"
## [1] "135E under condition BC10 at pH 5 on day 10 is not normal, with p value 0.0236855598327102"
## [1] "135E under condition BC10 at pH 7 on day 21 is not normal, with p value 0.00363798042890378"
## [1] "135E under condition BC9 at pH 5 on day 10 is not normal, with p value 0.0132655448752853"
## [1] "135E under condition BC9 at pH 7 on day 21 is not normal, with p value 0.00151130228982911"
## [1] "135E under condition JBC at pH 7 on day 10 is not normal, with p value 0.000130978175851881"
## [1] "135E under condition JB370 at pH 5 on day 3 is not normal, with p value 0.0164340900812654"
## [1] "135E under condition JB370 at pH 7 on day 21 is not normal, with p value 0.0041276667159235"
## [1] "135E under condition community at pH 7 on day 10 is not normal, with p value 0.0004103502809613"
## [1] "BC10 under condition 135E at pH 5 on day 21 is not normal, with p value 0.00781060853203707"
## [1] "BC10 under condition 135E at pH 7 on day 10 is not normal, with p value 0.0170835052562311"
## [1] "BC10 under condition BC9 at pH 7 on day 3 is not normal, with p value 0.00147089657967101"
## [1] "BC10 under condition JB370 at pH 7 on day 10 is not normal, with p value 0.0483983034429893"
## [1] "BC9 under condition alone at pH 7 on day 10 is not normal, with p value 0.00762595351665036"
## [1] "BC9 under condition 135E at pH 5 on day 21 is not normal, with p value 0.0344783997730223"
## [1] "BC9 under condition 135E at pH 7 on day 10 is not normal, with p value 0.0213691701556101"
## [1] "BC9 under condition BC10 at pH 5 on day 3 is not normal, with p value 0.0165480725535137"
## [1] "BC9 under condition JB7 at pH 5 on day 10 is not normal, with p value 0.00656400161774556"
## [1] "BC9 under condition JBC at pH 5 on day 21 is not normal, with p value 0.0284361347099042"
## [1] "BC9 under condition community at pH 5 on day 21 is not normal, with p value 0.00705687080831265"
## [1] "JB5 under condition alone at pH 5 on day 21 is not normal, with p value 0.000185326805471457"
## [1] "JB5 under condition alone at pH 7 on day 3 is not normal, with p value 0.0495906282507085"
## [1] "JB5 under condition 135E at pH 5 on day 3 is not normal, with p value 0.00285375736839026"
## [1] "JB5 under condition 135E at pH 7 on day 3 is not normal, with p value 0.000966138006960361"
## [1] "JB5 under condition BC10 at pH 5 on day 3 is not normal, with p value 0.000160894941090999"
## [1] "JB5 under condition JB7 at pH 5 on day 21 is not normal, with p value 0.0226956682386552"
## [1] "JB5 under condition JBC at pH 5 on day 21 is not normal, with p value 0.00124072593197728"
## [1] "JB5 under condition JBC at pH 7 on day 10 is not normal, with p value 0.000274017417407993"
## [1] "JB5 under condition community at pH 7 on day 3 is not normal, with p value 0.00244612098351583"
## [1] "JB7 under condition BC10 at pH 7 on day 3 is not normal, with p value 0.00124648390512589"
## [1] "JB7 under condition BC9 at pH 5 on day 10 is not normal, with p value 0.00124072593197728"
## [1] "JB7 under condition BC9 at pH 5 on day 21 is not normal, with p value 0.00126519925868427"
## [1] "JB7 under condition JB5 at pH 5 on day 21 is not normal, with p value 0.0119917440728649"
## [1] "JB7 under condition JBC at pH 5 on day 10 is not normal, with p value 0.000732525188384813"
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## [1] "JB7 under condition JBC at pH 5 on day 21 is not normal, with p value 0.000445725926986029"
## [1] "JB7 under condition JB370 at pH 5 on day 3 is not normal, with p value 0.0204384083887533"
## [1] "JB7 under condition JB370 at pH 5 on day 10 is not normal, with p value 0.0174983068565106"
## [1] "JB7 under condition community at pH 5 on day 10 is not normal, with p value 0.0260034687158117"
## [1] "JB7 under condition community at pH 5 on day 21 is not normal, with p value 0.0180158627938739"
## [1] "JBC under condition 135E at pH 5 on day 21 is not normal, with p value 0.0138750910563162"
## [1] "JBC under condition 135E at pH 7 on day 10 is not normal, with p value 0.00592509210178395"
## [1] "JBC under condition 135E at pH 7 on day 21 is not normal, with p value 0.030467402202482"
## [1] "JBC under condition JB7 at pH 5 on day 21 is not normal, with p value 0.00074479652512578"
## [1] "JBC under condition JB370 at pH 5 on day 10 is not normal, with p value 0.0248520407981874"
## [1] "JBC under condition JB370 at pH 7 on day 21 is not normal, with p value 0.0272315203612376"
## [1] "JBC under condition community at pH 7 on day 10 is not normal, with p value 0.0262302376598386"
## [1] "JB370 under condition alone at pH 7 on day 21 is not normal, with p value 0.0164371979814128"
## [1] "JB370 under condition BC9 at pH 5 on day 21 is not normal, with p value 0.0308696601645885"
## [1] "JB370 under condition JB5 at pH 7 on day 21 is not normal, with p value 0.0415122140334583"
## [1] "JB370 under condition JB7 at pH 7 on day 10 is not normal, with p value 0.0110923610408406"
## [1] "JB370 under condition JBC at pH 5 on day 21 is not normal, with p value 0.00136579826717061"
## [1] "JB370 under condition community at pH 5 on day 21 is not normal, with p value 0.000371360225512"
## [1] "JB370 under condition community at pH 7 on day 10 is not normal, with p value 0.001943306550283"
```

Obviously, many samples are not normally distributed. Ah, biology. Anyway. Does log10 transformation help?

Are log-transformed data normally distributed? – run shapiro tests

```
## [1] "135E CFUs under condition alone at pH 5 on day 3 is not normal, with p value 0.0143747852213376"
## [1] "135E CFUs under condition alone at pH 5 on day 10 is not normal, with p value 0.005607309703826"
## [1] "135E CFUs under condition BC10 at pH 5 on day 3 is not normal, with p value 0.00349514083979846"
## [1] "135E CFUs under condition BC10 at pH 5 on day 10 is not normal, with p value 0.0142225978464668"
## [1] "135E CFUs under condition BC9 at pH 5 on day 10 is not normal, with p value 0.0387124052991384"
## [1] "135E CFUs under condition BC9 at pH 7 on day 21 is not normal, with p value 0.0192794654067061"
## [1] "135E CFUs under condition JB7 at pH 5 on day 10 is not normal, with p value 0.0237194611771649"
## [1] "135E CFUs under condition JB370 at pH 5 on day 3 is not normal, with p value 0.0103114258613383"
## [1] "135E CFUs under condition JB370 at pH 7 on day 21 is not normal, with p value 0.040169329534045"
## [1] "135E CFUs under condition community at pH 7 on day 10 is not normal, with p value 0.00544615874"
## [1] "BC10 CFUs under condition 135E at pH 5 on day 3 is not normal, with p value 0.0181878113862117"
## [1] "BC10 CFUs under condition 135E at pH 5 on day 21 is not normal, with p value 0.0458805693209539"
## [1] "BC10 CFUs under condition BC9 at pH 7 on day 3 is not normal, with p value 0.0085701786250114"
## [1] "BC10 CFUs under condition JB7 at pH 5 on day 21 is not normal, with p value 0.00747166936411928"
## [1] "BC10 CFUs under condition JBC at pH 5 on day 10 is not normal, with p value 0.0351143402341352"
## [1] "BC10 CFUs under condition JB370 at pH 5 on day 3 is not normal, with p value 0.03350090482172"
## [1] "BC9 CFUs under condition alone at pH 7 on day 10 is not normal, with p value 0.0098019108867509"
## [1] "BC9 CFUs under condition 135E at pH 7 on day 10 is not normal, with p value 0.0102282173340698"
## [1] "BC9 CFUs under condition BC10 at pH 7 on day 21 is not normal, with p value 0.00882140610866051"
## [1] "BC9 CFUs under condition JB7 at pH 7 on day 21 is not normal, with p value 0.00390529713993164"
## [1] "BC9 CFUs under condition JB370 at pH 5 on day 21 is not normal, with p value 0.0277501731274113"
## [1] "JB5 CFUs under condition BC10 at pH 5 on day 21 is not normal, with p value 0.0403226957986912"
## [1] "JB5 CFUs under condition BC9 at pH 5 on day 3 is not normal, with p value 0.0108911676854259"
## [1] "JB5 CFUs under condition community at pH 7 on day 3 is not normal, with p value 0.0084704988123"
## [1] "JB7 CFUs under condition alone at pH 5 on day 3 is not normal, with p value 0.0477748559436358"
## [1] "JB7 CFUs under condition BC10 at pH 5 on day 21 is not normal, with p value 0.00338523074669805"
## [1] "JB7 CFUs under condition BC9 at pH 5 on day 10 is not normal, with p value 0.00124072593197728"
## [1] "JB7 CFUs under condition JB370 at pH 7 on day 21 is not normal, with p value 0.0437452224464905"
## [1] "JBC CFUs under condition 135E at pH 7 on day 21 is not normal, with p value 0.0118093963058239"
## [1] "JBC CFUs under condition JB7 at pH 5 on day 21 is not normal, with p value 0.00516390863031649"
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## [1] "JBC CFUs under condition JB7 at pH 7 on day 10 is not normal, with p value 0.0244834762952324"
## [1] "JBC CFUs under condition JB370 at pH 5 on day 10 is not normal, with p value 0.0298345669053979"
## [1] "JB370 CFUs under condition JB5 at pH 7 on day 21 is not normal, with p value 0.0259871796710247"
## [1] "JB370 CFUs under condition community at pH 7 on day 10 is not normal, with p value 0.0347855208"
```

Better but still many samples are not normally distributed.

Thinking ahead to the t-tests we'll want to do to compare coculture growth to alone growth, let's check how similar variances are between comparable samples. – Levene's Test (of equality of variances for non-normally distributed data) Start with raw colony-forming units:

```
## [1] "135E CFUs alone versus with JBC at pH 5 on day 21 do not have equal variance, with p value 0.0244834762952324"
## [1] "135E CFUs alone versus with community at pH 5 on day 21 do not have equal variance, with p value 0.0298345669053979"
## [1] "BC10 CFUs alone versus with JB370 at pH 5 on day 21 do not have equal variance, with p value 0.0259871796710247"
## [1] "BC10 CFUs alone versus with community at pH 5 on day 21 do not have equal variance, with p value 0.0347855208"
## [1] "BC9 CFUs alone versus with JB370 at pH 5 on day 21 do not have equal variance, with p value 0.0244834762952324"
## [1] "JB5 CFUs alone versus with BC10 at pH 5 on day 21 do not have equal variance, with p value 0.0298345669053979"
## [1] "JB5 CFUs alone versus with BC9 at pH 5 on day 10 do not have equal variance, with p value 0.0347855208"
## [1] "JB5 CFUs alone versus with JBC at pH 5 on day 10 do not have equal variance, with p value 0.0244834762952324"
## [1] "JB5 CFUs alone versus with JBC at pH 7 on day 10 do not have equal variance, with p value 0.0102471796710247"
## [1] "JB5 CFUs alone versus with JBC at pH 7 on day 21 do not have equal variance, with p value 0.047102471796710247"
## [1] "JB5 CFUs alone versus with JB370 at pH 5 on day 10 do not have equal variance, with p value 0.0298345669053979"
## [1] "JB5 CFUs alone versus with JB370 at pH 7 on day 10 do not have equal variance, with p value 0.0347855208"
## [1] "JB5 CFUs alone versus with community at pH 5 on day 10 do not have equal variance, with p value 0.0244834762952324"
## [1] "JB5 CFUs alone versus with community at pH 7 on day 10 do not have equal variance, with p value 0.0298345669053979"
## [1] "JB5 CFUs alone versus with community at pH 7 on day 21 do not have equal variance, with p value 0.0259871796710247"
## [1] "JB7 CFUs alone versus with 135E at pH 5 on day 10 do not have equal variance, with p value 0.00347855208"
## [1] "JB7 CFUs alone versus with 135E at pH 7 on day 21 do not have equal variance, with p value 0.0347855208"
## [1] "JB7 CFUs alone versus with JBC at pH 7 on day 3 do not have equal variance, with p value 0.031347855208"
## [1] "JB7 CFUs alone versus with JBC at pH 7 on day 10 do not have equal variance, with p value 0.02347855208"
## [1] "JB7 CFUs alone versus with community at pH 5 on day 3 do not have equal variance, with p value 0.0102471796710247"
## [1] "JB7 CFUs alone versus with community at pH 7 on day 10 do not have equal variance, with p value 0.0347855208"
## [1] "JBC CFUs alone versus with 135E at pH 5 on day 3 do not have equal variance, with p value 0.0167102471796710247"
## [1] "JBC CFUs alone versus with community at pH 5 on day 3 do not have equal variance, with p value 0.0102471796710247"
## [1] "JB370 CFUs alone versus with community at pH 5 on day 10 do not have equal variance, with p value 0.0298345669053979"
```

That's also not great. What happens to variances when CFU data is log-transformed? – Levene's Test (of equality of variances for non-normally distributed data)

```
## [1] "135E CFUs alone versus with JBC at pH 5 on day 10 do not have equal variance, with p value 0.047102471796710247"
## [1] "BC10 CFUs alone versus with JBC at pH 5 on day 21 do not have equal variance, with p value 0.00347855208"
## [1] "BC9 CFUs alone versus with community at pH 5 on day 10 do not have equal variance, with p value 0.0102471796710247"
## [1] "JB7 CFUs alone versus with JBC at pH 5 on day 21 do not have equal variance, with p value 0.0102471796710247"
## [1] "JB7 CFUs alone versus with JB370 at pH 5 on day 21 do not have equal variance, with p value 0.0298345669053979"
## [1] "JB7 CFUs alone versus with community at pH 5 on day 21 do not have equal variance, with p value 0.0244834762952324"
## [1] "JBC CFUs alone versus with community at pH 5 on day 3 do not have equal variance, with p value 0.0102471796710247"
## [1] "JB370 CFUs alone versus with JBC at pH 7 on day 10 do not have equal variance, with p value 0.0347855208"
```

Just like for normality, that's a bit better.

But the problem with log-transformed data is it turns real 0's into infinite numbers. And those can't be statistically assessed. So I lose lots of very real information when these zero-values are practically eliminated.

So no log-transformation, despite its help in normalizing sample distributions. **Also use non-parametric tests.** Wilcoxon Rank-Sums tests compare the shift in two samples.