Experimental design and field biology

“Doing science”

“Science” is something like:

Making observations about the real world and interpreting those observations

“Doing science”

What is “good science”?

Assumptions like:

Objective, systematic, repeatable, refutable…

Methods + Data + Interpretation = “science”

Interpretation can change…

Starting point:

Your **BIG** question – something about how the world is, how the world works, or why the world works the way it does

(1) How does it work?

mechanistic question

(2) Why is it like that?

functional question

Some sort of process:

(1) Observations → Question(s)

(2) Question(s) → Hypothesis

(3) Hypothesis → Predictions
(allow test of H)

(4) Update hypothesis → New predictions

Some sort of process:

(1) Observations	→	Question(s)
Distribution of winkles		Why?
(2) Question(s)	→	Hypothesis
Why?		Competition
(3) Hypothesis	→	Predictions
Competition		Change distribution if manipulate competition

Do results confirm prediction?

Trying to explain the world

The “WORLD” ~ SOMETHING + “NOISE”

SOMETHING = derived from a hypothesis/hunch

Noise = “residual error” or “error”

The “WORLD” ~ SOMETHING + “NOISE”

Barnacle distribution ~ Inter-spp competition + Noise

Variation in plumage ~ Sexual selection + Noise

Plant height ~ Wind exposure + Noise

Insect diversity ~ Vegetation complexity + Noise

Hermit crab fights ~ Body size + Noise

The “WORLD” ~ SOMETHING + “NOISE”

Barnacle distribution ~ Inter-spp competition + Noise

Variation in

Plant heigh

“Noise” can still contain interesting “somethings”, but have to start somewhere…

Insect diversity ~ Vegetation complexity + Noise

Hermit crab fights ~ Body size + Noise

The “WORLD” ~ SOMETHING + “NOISE”

“Something” is/ comes from your Hypothesis

↓

Predict “World” if Hypothesis is true

↓

Vary “Something” (observations/experiment)

←

Does exptal “World” fit predictions?

Types of fieldwork:

Descriptive and/or Experimental

The “WORLD” ~ SOMETHING + “NOISE”

TWO approaches

(1) OBSERVE the “something” and see if related to “world”

TEST PREDICTION: there is a *particular* relationship

(2) MANIPULATE the “something” and see if “world” changes (i.e. do an experiment)

TEST PREDICTION: there is a *particular* change

The “WORLD” ~ SOMETHING + “NOISE”

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TEST PREDICTION: there is a *particular* change

PREDICTION: “how would we know?”

An example

Aggregation in the snail *Theba pisana*

An example

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Q: why do some snails aggregate?

An example

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Hypothesis: Snails aggregate to avoid dessication

An example

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Hypothesis: Snails aggregate to reduce predation

An example

Aggregation in the snail *Theba pisana*

Q: why do some snails aggregate?

Hypothesis: Snails aggregate to avoid dessication

Hypothesis: Snails aggregate to reduce predation

Hypothesis: .....

Hypothesis: Snails aggregate to avoid dessication

Hypothesis: Snails aggregate to reduce predation

Generate ***predictions*** that ***discriminate*** between hypotheses

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Hypothesis: Snails aggregate to reduce predation

Generate ***predictions*** that ***discriminate*** between hypotheses

Prediction: snails aggregate where drier/windier/less shelter

Prediction: snails aggregate when more vulnerable to predators (smaller?)

Hypothesis: Snails aggregate to avoid dessication

Hypothesis: Snails aggregate to reduce predation

Generate ***predictions*** that ***discriminate*** between hypotheses

Prediction: snails aggregate where drier/windier/less shelter

Prediction: snails aggregate when more vulnerable to predators (smaller?)

Often hard to generate definitive predictions: this is real science (and why we love “elegant experiments”)

Hypotheses tested by seeing if **predictions** hold true or not

Rarely cut and dried answers...

The more you think about predictions, the less lost you will be when you get data...

The “WORLD” ~ SOMETHING + “NOISE”

Statistics mirrors this “inference equation”

e.g. DATA ~ TREATMENT + NOISE

Statistics test whether TREATMENT explains data

The “WORLD” ~ SOMETHING + “NOISE”

Statistics mirrors this “inference equation”

e.g. DATA ~ NOISE ☹

DATA ~ TREATMENT + NOISE ☺

DATA ~ TREATMENT + $_{\text{NOISE}}$ ☺ ☺ ☺

All statistics can be formalised as a “LINEAR MODEL”

Key component 1: replication

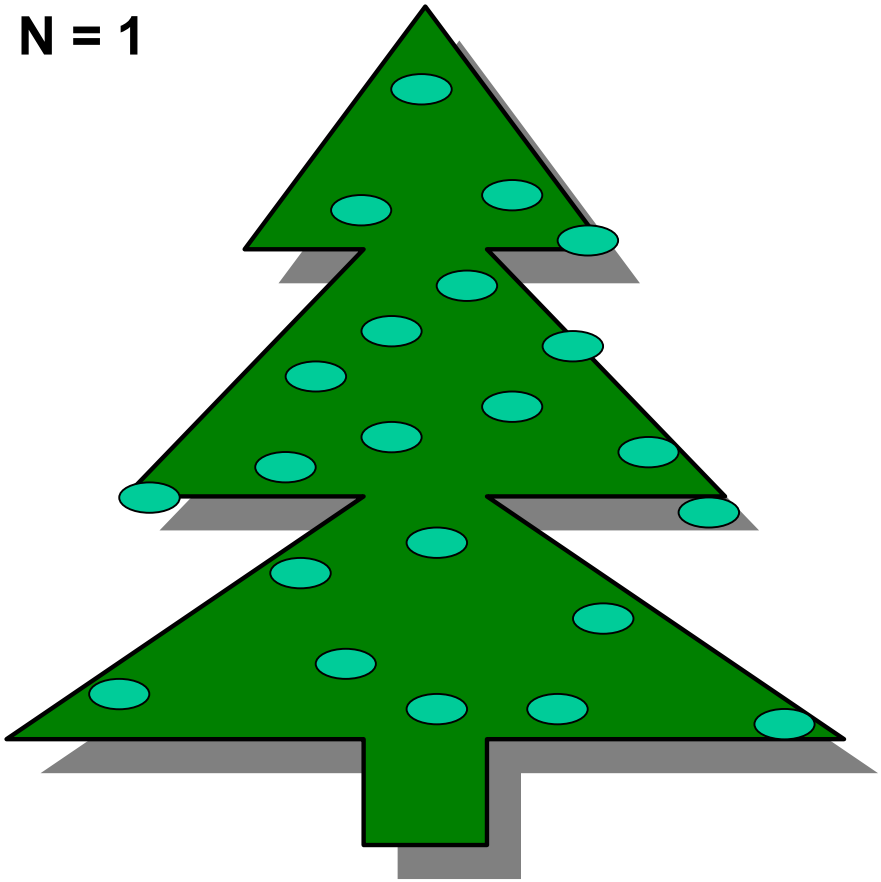
To make sensible inferences/do statistics, you need to have replicate samples…

Transects, questionnaires, pit-fall traps, observation periods, rock samples, animals, plants, GIS records…

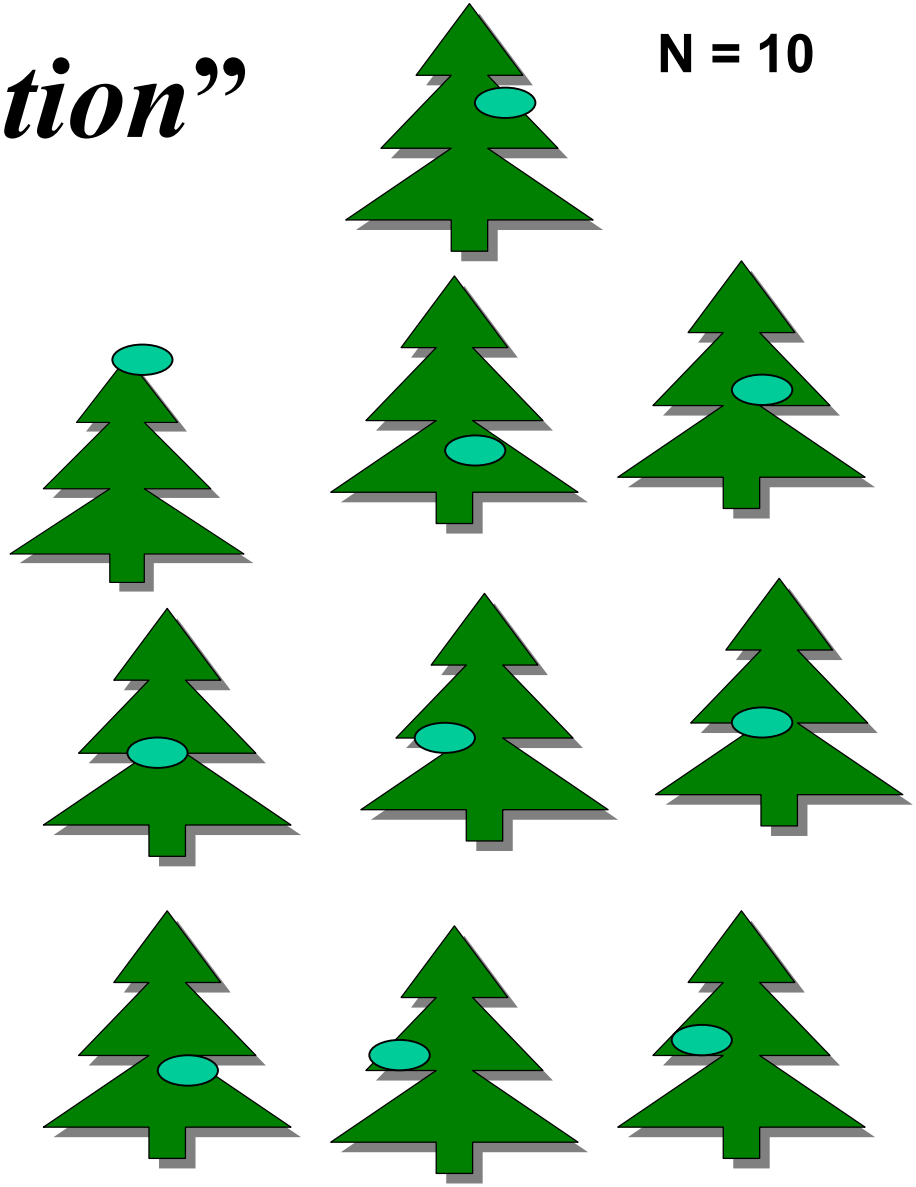
Replicate samples must be **independent**

"Pseudoreplication"

N = 1



N = 10



Key component 2: comparisons

Often will want to make comparisons to test predictions

Control treatments, control transects, multiple habitats

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Control treatments, control transects, multiple habitats

What factors **confound** your comparison?

Time of day, who does the sampling, date, aspect, different ecological community, different geology, different histories…

Balancing replicates and comparisons

Usually: replicates *versus* comparisons

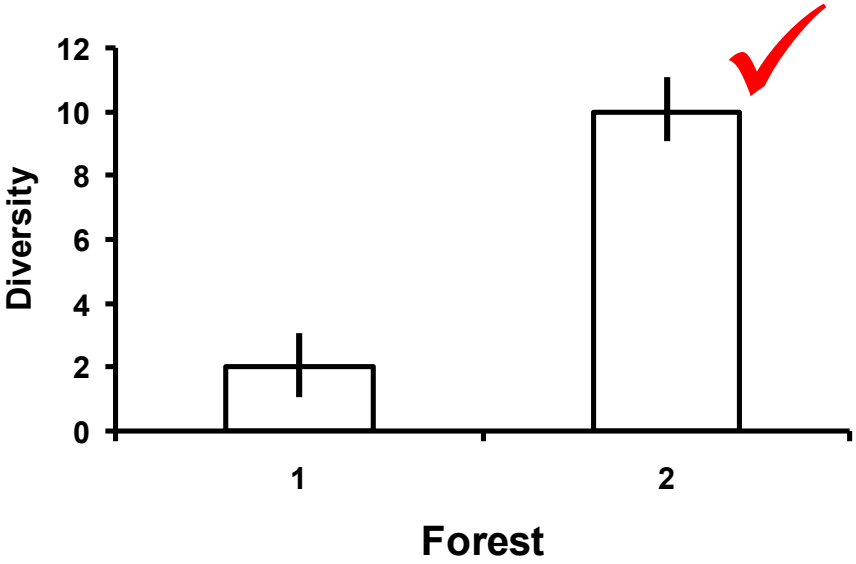
Sample size will be a compromise

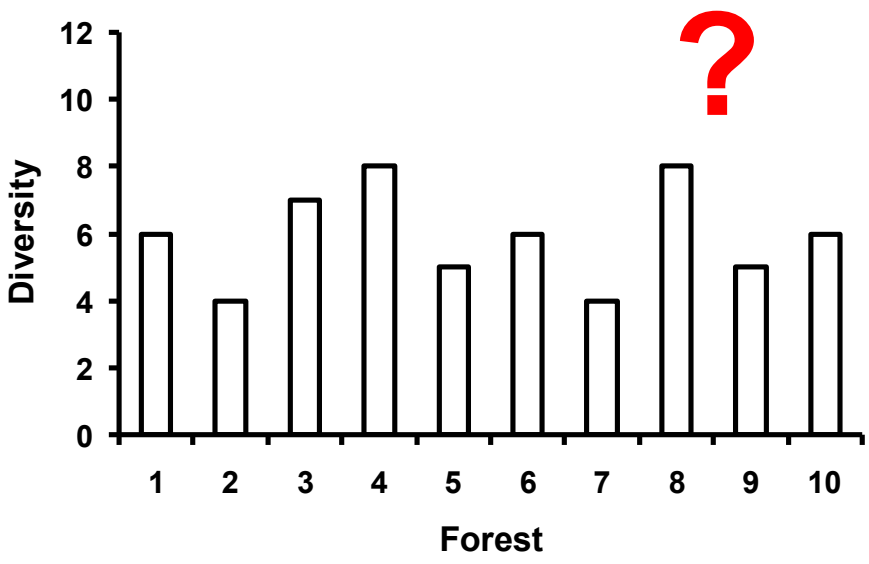
2 types of forest, 10 samples of each

or

10 types of forest, 2 samples of each

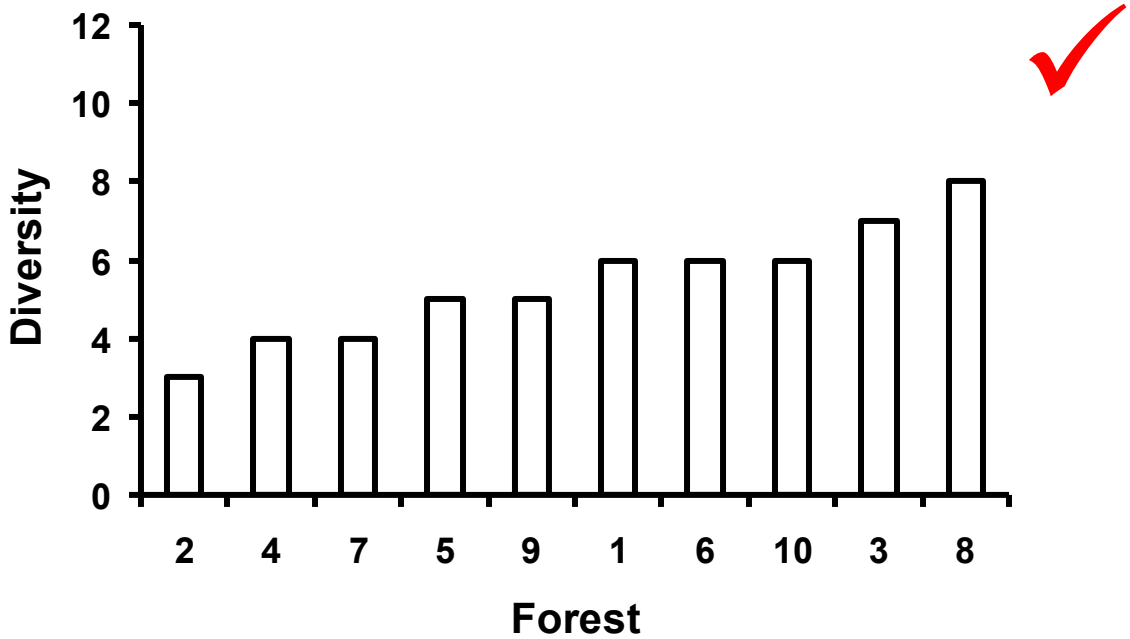
Balancing replicates and comparisons





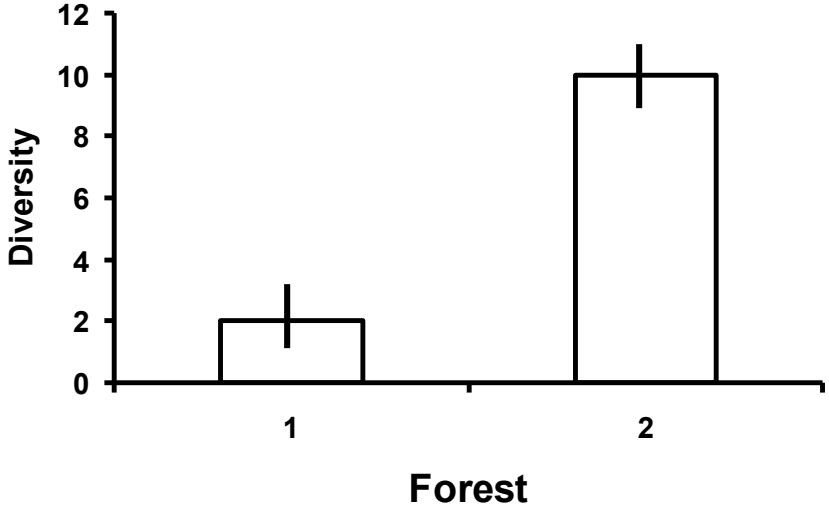
Balancing replicates and comparisons

If there is an environmental gradient



Increasing humidity →

Plan analysis before you start!



Make up some data and practise analysing it

Talk to tutors about appropriate analysis

Find papers/books that have done similar things?

Sampling strategy

1) Random sampling

Make sure random is **random**!

(Lottery, random numbers etc)

Least biased method

					*
	*				
		*	*		
	*				
		*			

				*	
	*		*		*
	*				
					*
	*		*		
			*		

Sampling strategy

2) Systematic sampling

Need to complete the sampling regime & possible biases

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*		*		*	
	*		*		*
*		*		*	
	*		*		*
*		*		*	

	*			*	
	*			*	

Sampling strategy

3) Stratified sampling

Possible biases but can be flexible

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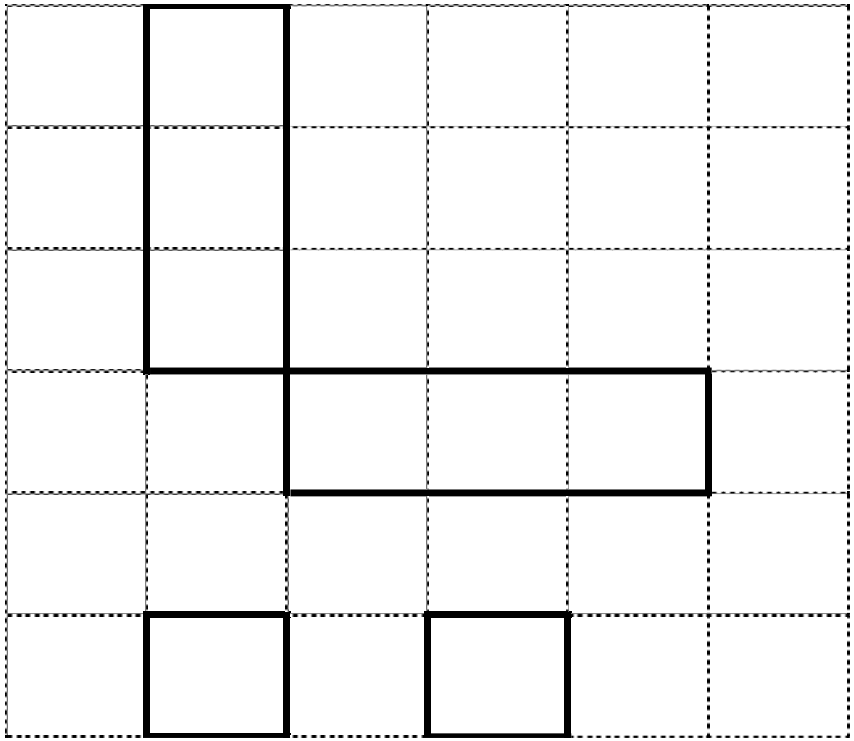
*	*				
				*	
			*		
					*

	*				
*	*	*		*	
		*			
	*			*	
		*	*	*	
				*	*

Sampling strategy

4) Real Life!



Do the best you can…

Do the best you can…

Experiments & Manipulations

Remember a “control” group that *nothing* happens to (even if it seems silly)

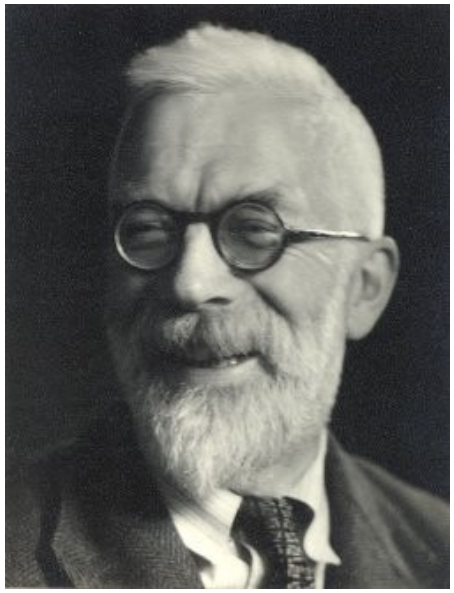
Statistics: a refresh(ing) course

Statistics are a tool (they are *not* in control)

If you measured or counted every individual in the world, you would *not need* statistics

We use statistics because we are taking (small) **SAMPLES** to see if a difference or association is **REAL**

Thanks to mathematicians…



…statistics allow us to assess the probability that a given **difference** or **association** occurred by ***chance***

Different statistics:

(1) test different kinds of data

counts, ranks, or measurements

(2) use different probability distributions

Normal, binomial, chi-square…

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Normal, binomial, chi-square…

For a given sample size, a given difference or association has a certain probability of occurring by <u>chance</u> – this is the "**P value**"

By convention:

$P < 0.05$ we say a given effect is *significant*

(i.e. we accept 1 in 20, or 5%, of times the effect has occurred by chance, but live with it)

NO formal justification for this

Just a balance of different ways of being wrong

Therefore we are “happier” if

$P < 0.01$, or 0.001, or 0.0001

(i.e. less likely to occur by chance)

BUT *statistical significance* is NOT the same as thing as *biological significance*

How much data?

Small samples are not bad IF difference or association is **strong**

E.g. you do an experiment where you predict a **big** difference

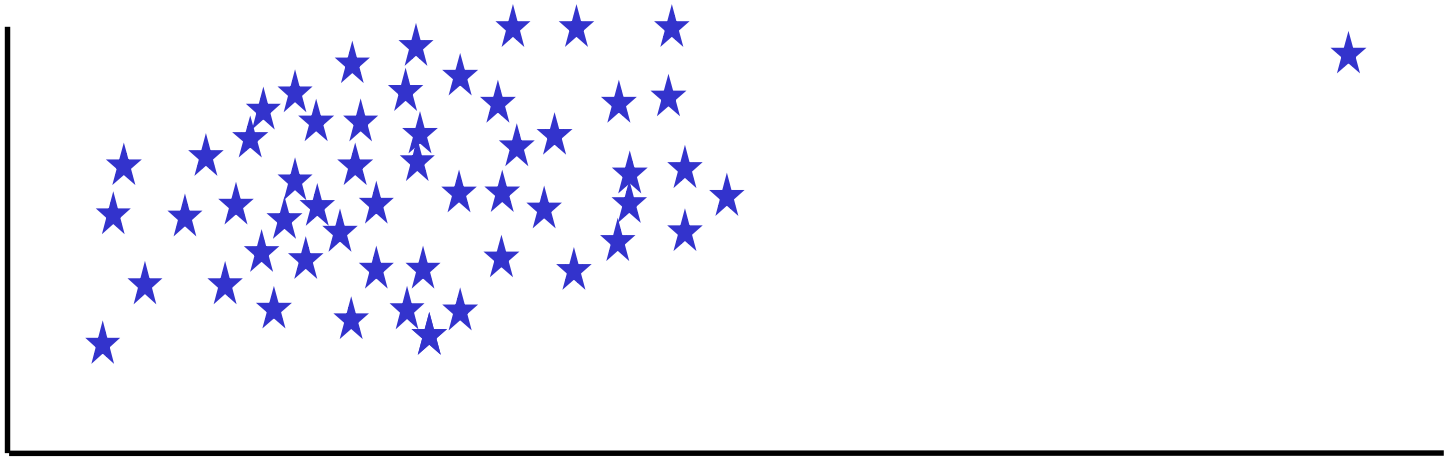
Statistics HARD if N < 5 replicates per treatment

Statistics EASIER if N > 30 replicates per treatment

BEFORE YOU START CHOOSING A TEST:

Look at your data: draw figures

Draw plots, histograms, and so on



BEFORE YOU START CHOOSING A TEST:

Look at your data: draw figures

Draw plots, histograms, and so on

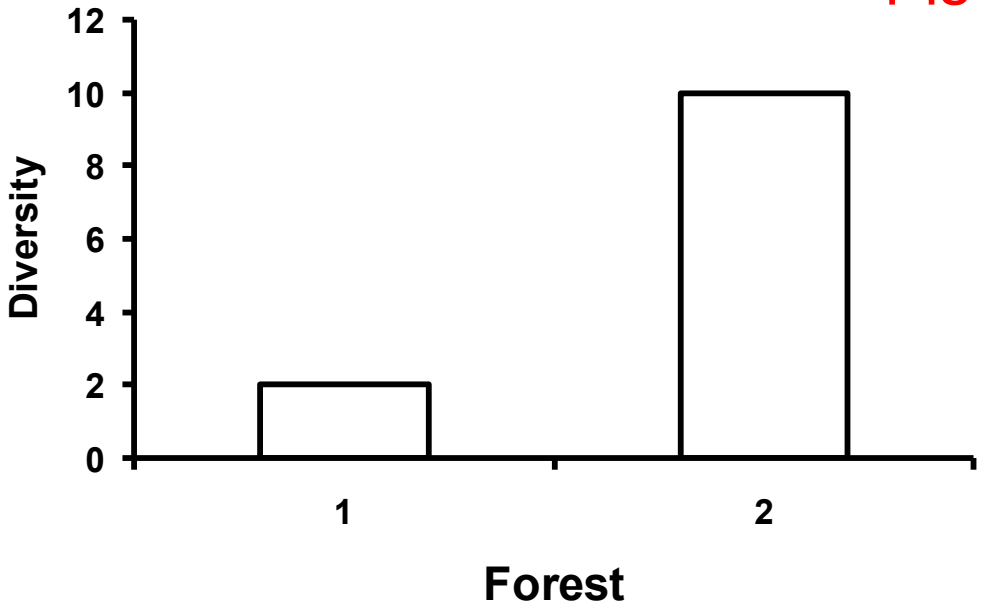
Statistics should **confirm** what appears on a figure

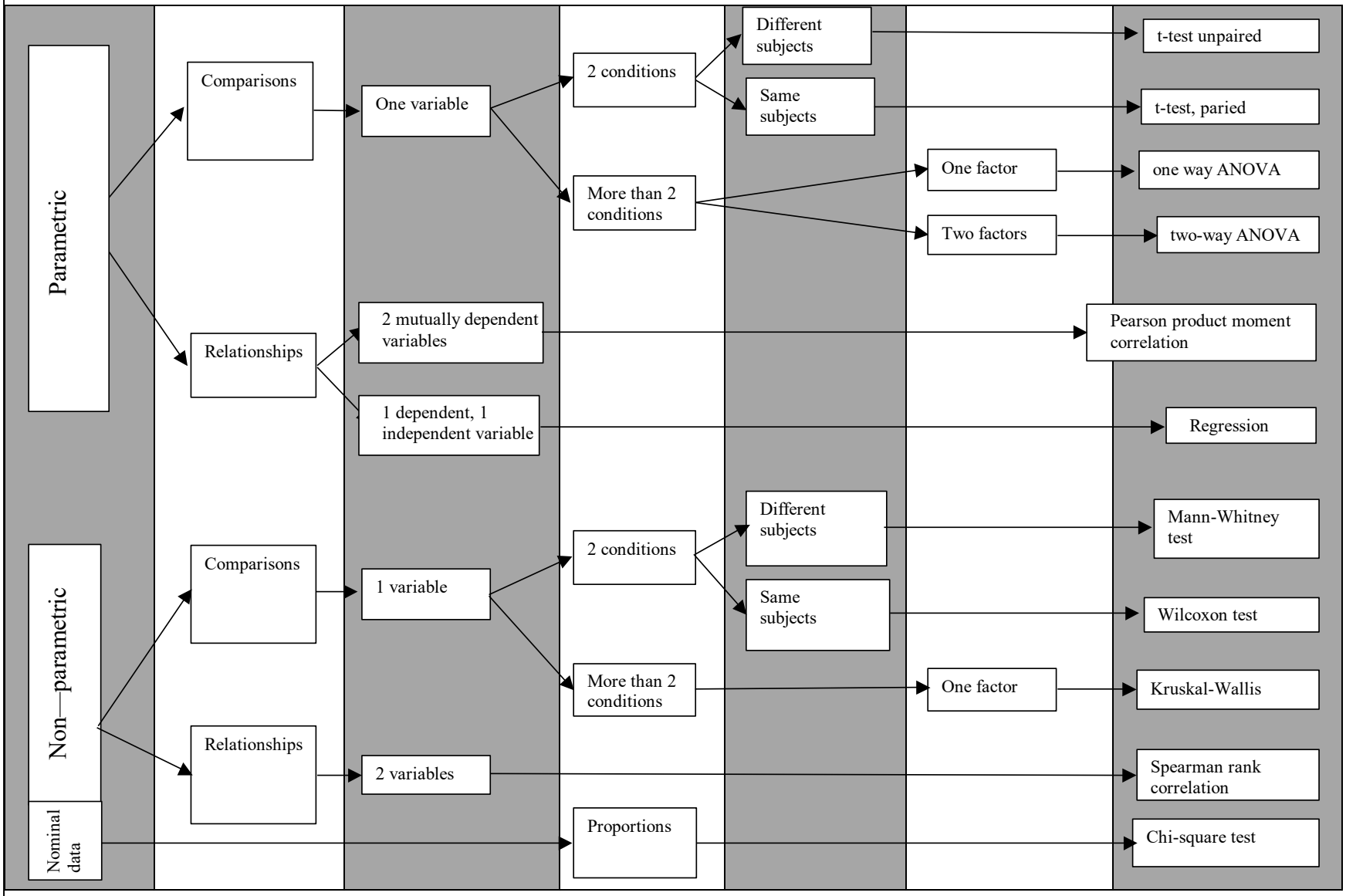
(e.g. can you explain everything with a figure, even if you use stats to justify a difference/relationship?)

BEFORE YOU START CHOOSING A TEST:

Look at your data: draw figures

STATS should say 1 is different to 2…




Parametric
Comparisons
One variable
2 conditions
Different subjects
t-test unpaired
Same subjects
t-test, paried
More than 2 conditions
One factor
one way ANOVA
Two factors
two-way ANOVA
Relationships
2 mutually dependent variables
Pearson product moment correlation
1 dependent, 1 independent variable
Regression
Non—parametric
Comparisons
1 variable
2 conditions
Different subjects
Mann-Whitney test
Same subjects
Wilcoxon test
More than 2 conditions
One factor
Kruskal-Wallis
Relationships
2 variables
Spearman rank correlation
Nominal data
Proportions
Chi-square test

Ethics & welfare

Respect the environment and the organisms in it

Too many **or** too few samples may waste/deplete resources for no good reason

Only accumulate samples/data that you will analyse

Increase sample sizes with harmless or “sham” controls rather than invasive or stressful experimental treatments

(AND in other contexts: write up & publish!)

“Golden rules”

- Be realistic
- Practise data collection/pilot study
- Write everything down
- Store data/notes carefully (triplicate…!)
- Expect things to go wrong
- Do not throw data/samples away
- Cost:Benefit of different types of data
- Remember predictions
- Eyeball & check data