Quick Stats Review

- Asking Questions in Science
  - Experimental Design
    - Replication and randomization, independence
    - Confounding factors
    - Manipulation and natural experiments
- Do the Analysis –*The Matrix* (see last slide) will tell you which statistical tests to run for what kinds of variables. Ask:
  - What is my independent (x) variable
  - What is my dependent (y) variable (aka response var)
  - What are their ‘types’
- Interpret your results

Asking questions in science

- Focus the question
- What are the variables?
- What are your hypotheses? Research & Null
- Design the study
- Gather data
- Analyze data – look for patterns, use statistics
- Were your hypotheses supported?
- Conclusions… & design of new studies to answer new research questions

Experimental Design

- Observations- what we see and measure in the real world
- Hypotheses- potential explanations that account for our observations
- Well-designed studies allow us to be confident in the inferences we draw from our studies
- A scientific hypothesis must be testable!

Proper replication

- How many replicates (plots, samples, treatments) are required?
  - Depends on the effect size & variance
  - Difficult to estimate
  - Pilot studies are expensive
  - Estimate from previous studies…
  - Depends on time, money & labor

Rule of 10

- As a general rule, you should have 10 replicate observations of each treatment (Law of Large Numbers)
- Many ecological experiments have fewer than 10 replicates out of necessity
- Fewer replicates run the risk of the noise outweighing the pattern – loss of "power"

Exceptions to the Rule of 10

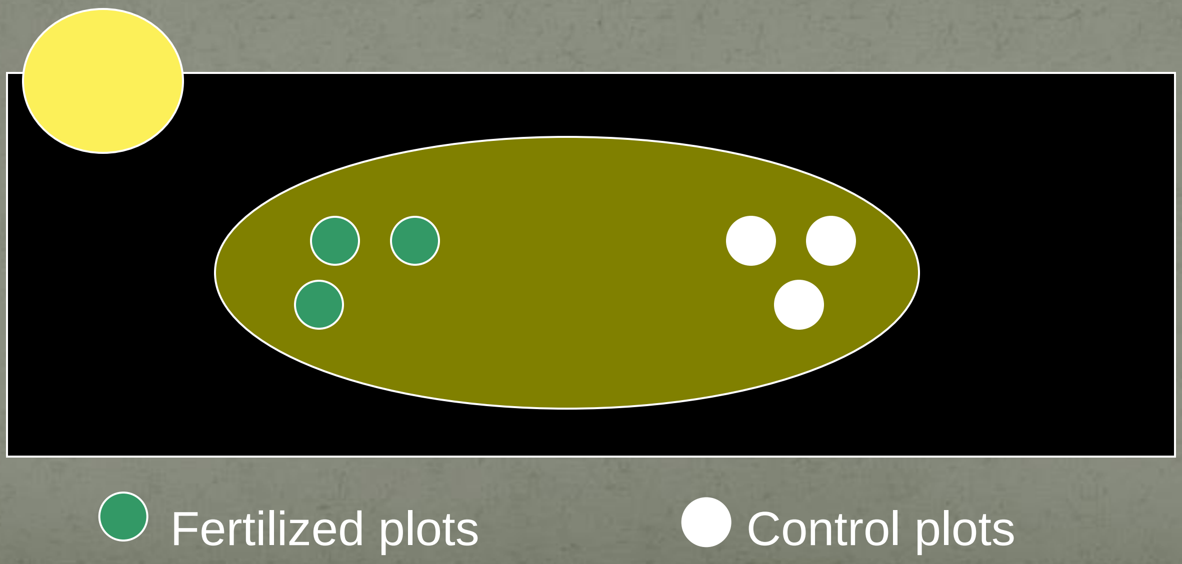
- Large-scale ecosystem experiments – impossible to replicate 10 times
  - e.g., whole-lake manipulations
- Environmental impact studies – assessing an impact at a single site
  - Requires a special “Before-After Control Impact” (BACI) design

Independence

- Measurement 1 does not affect measurement 2, etc.
  - Plot proximity – Fertilizer treatments may affect downstream "controls"
  - Can affect both manipulative & natural experiments
- Separating plots too far may introduce new confounding variables due to heterogeneity

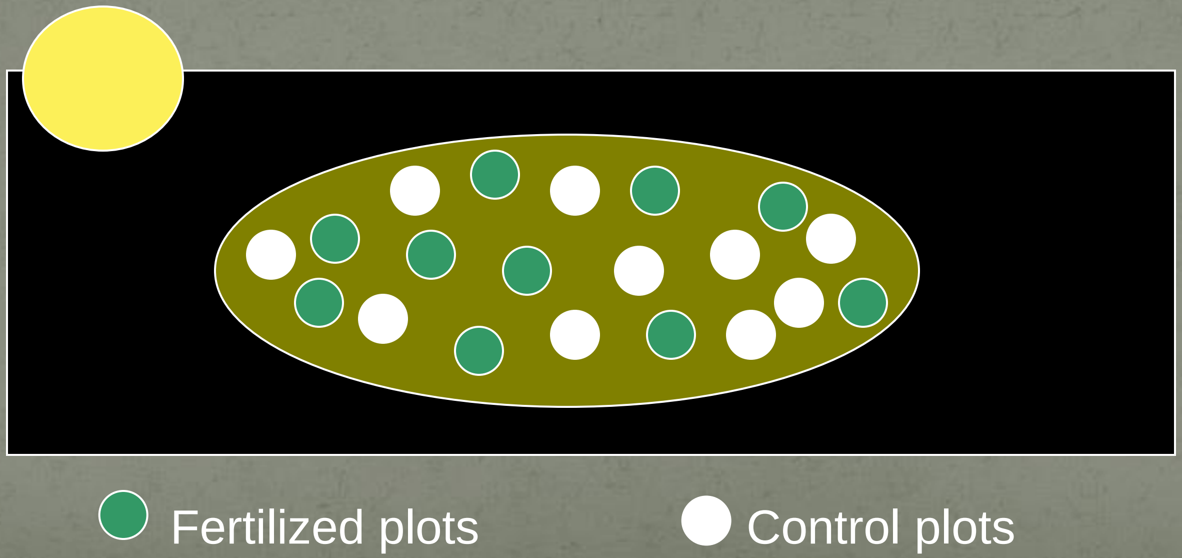
Avoiding Confounding Factors

- What if fertilized plots accidentally ended up on sunny hillsides and control plots were shady?
- Treatments are confounded with temp.



Avoiding Confounding Factors

- Replication & Randomization can help
  - Replicate both treatment & control 10 times
  - Randomize treatments & controls across landscape



Natural Experiments

- An observational study – taking advantage of natural variation in a variable of interest
- e.g., compare lizard & spider densities on different islands.
- Often confounded – unlikely that islands will be identical other than just spider & lizard densities
- Difficult to make causal claims

Manipulations vs. Natural experiments

- Manipulative experiments allow for greater confidence in our inferences of cause & effect
- But, they are confined to small spatial scales and short time frames
- Natural experiments can be conducted at any spatial scale & any time interval
- But, more difficult to tease apart cause & effect relationships

2 Types of Natural Experiments

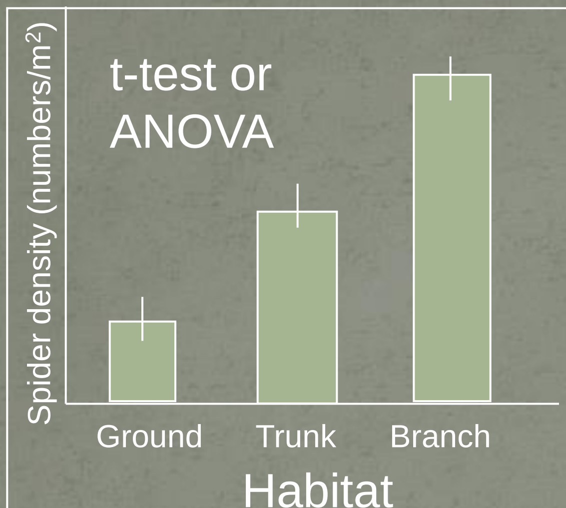
- Snapshot experiment: replicated in space
  - Rapid data collection
  - Spatial replicates are independent
  - Majority of ecological experiments
  - Chronosequences mimic trajectory exps.

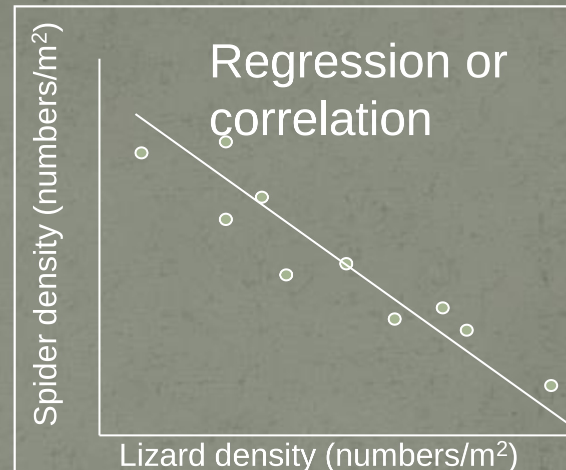
2 Types of Manipulations

- Press experiments: treatments maintained through time – reapplied to maintain constancy
  - e.g., reapplication of fertilizer to maintain N
  - Measures resistance to disturbance
- Pulse experiments: treatments applied only once and systems allowed to recover
  - Measures resilience to disturbance

4 Basic Experiments

Continuous Y





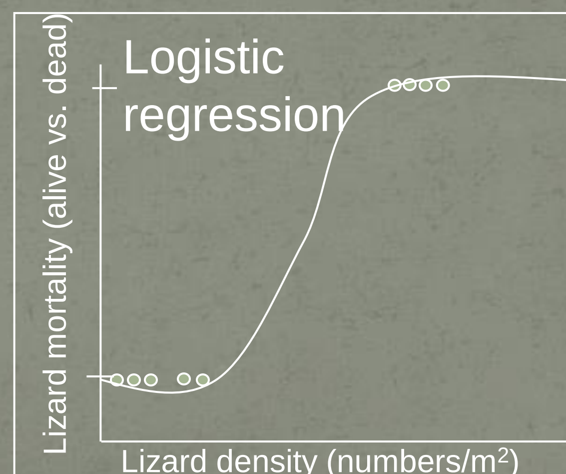
Categorical Y

Contingency table

Lizard mortality (alive vs. dead)

	Ground	Trunk	Branch
	17	12	9
	4	8	15

Habitat



But others include:

ANCOVA

MANOVA

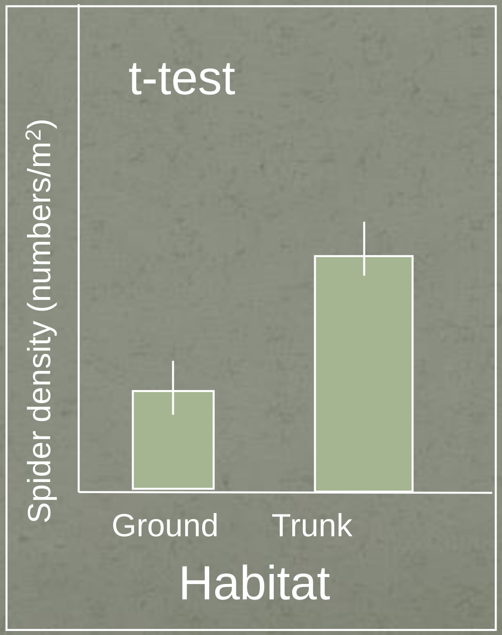
Multivariate

Modeling

Categorical X **Continuous X**

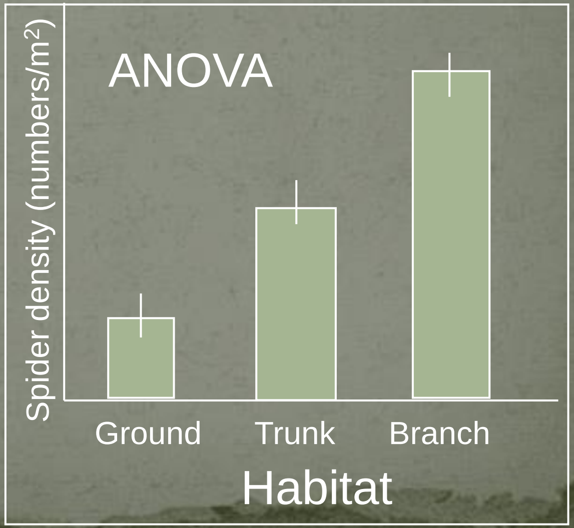
t-tests – comparing 2 means

- Comparing means between 2 treatments or a treatment and a control
- We will work with these kinds of tests in lab…

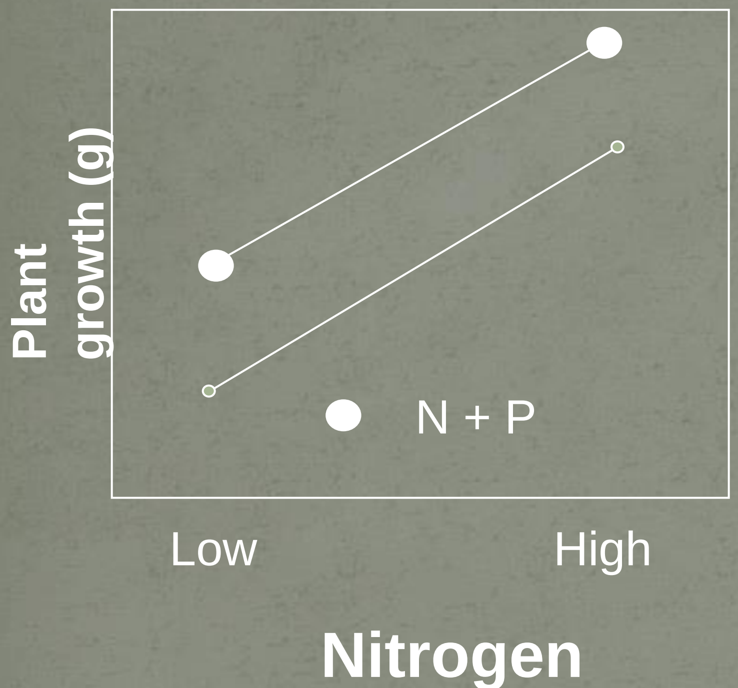


ANOVA models – comparing many means

- Most ecological data are analyzed using ANOVA models:
- One-way: One treatment of interest
- Two-way: Two treatments of interest – allows you to examine main effects and interaction effects – see Fig 7.4



Statistical Interactions



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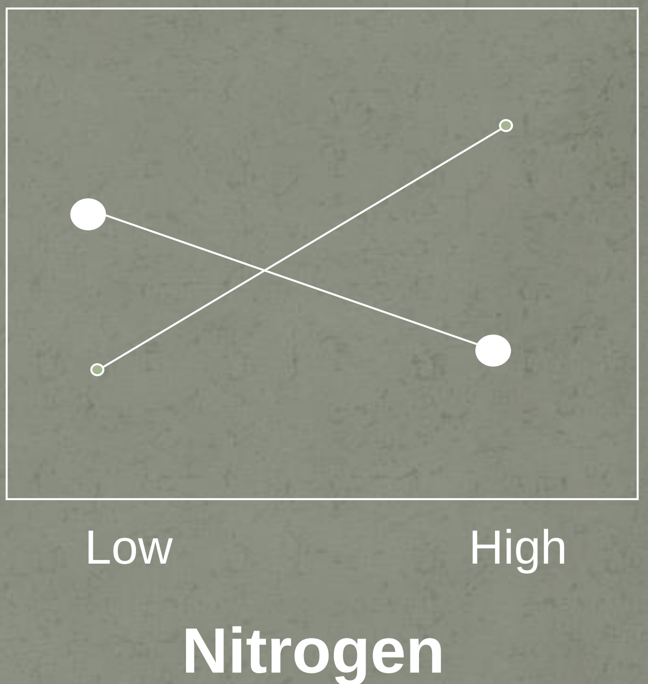


No interaction of N & P – purely additive response where both factors increase plant growth

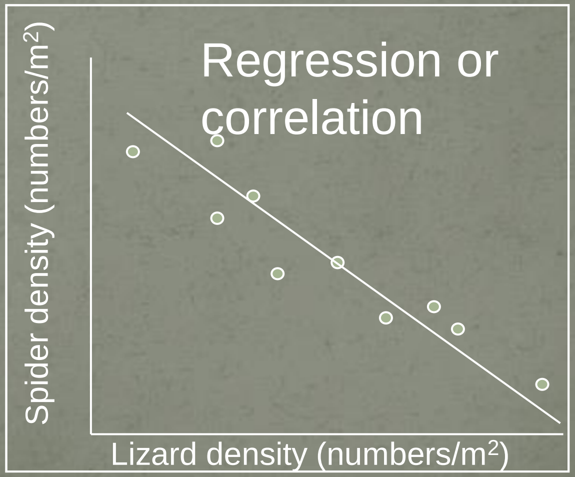
Interaction between N & P where at low levels of N, P increases plant growth, but at high levels of N, P decreases plant growth

Types of ANOVA

- Randomized block design
- Split-plot designs
- Nested designs
- Repeated measures designs
- BACI designs

Regression models – linear relationships

- Make sure you sample across the range of possibilities – could confound your patterns – see Figs 7.2 & 7.3
- Can be very powerful –



t-tests – comparing 2 means

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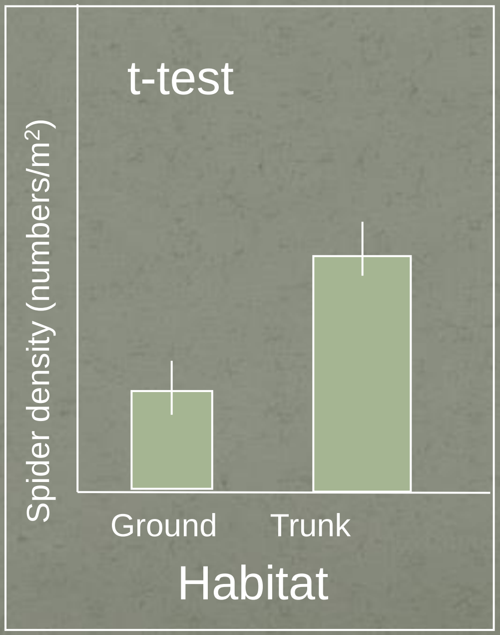
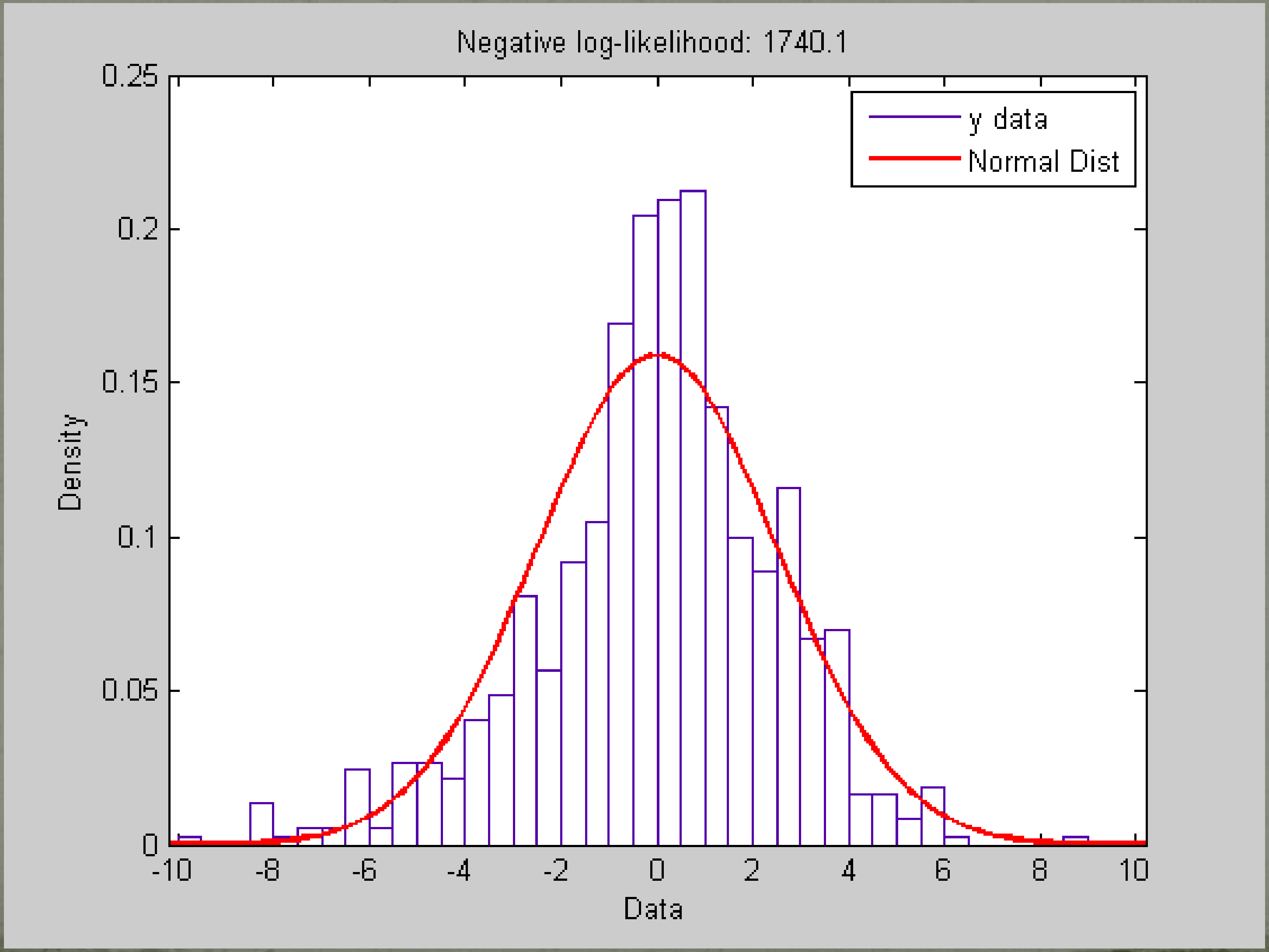


Remember the Normal Distribution?



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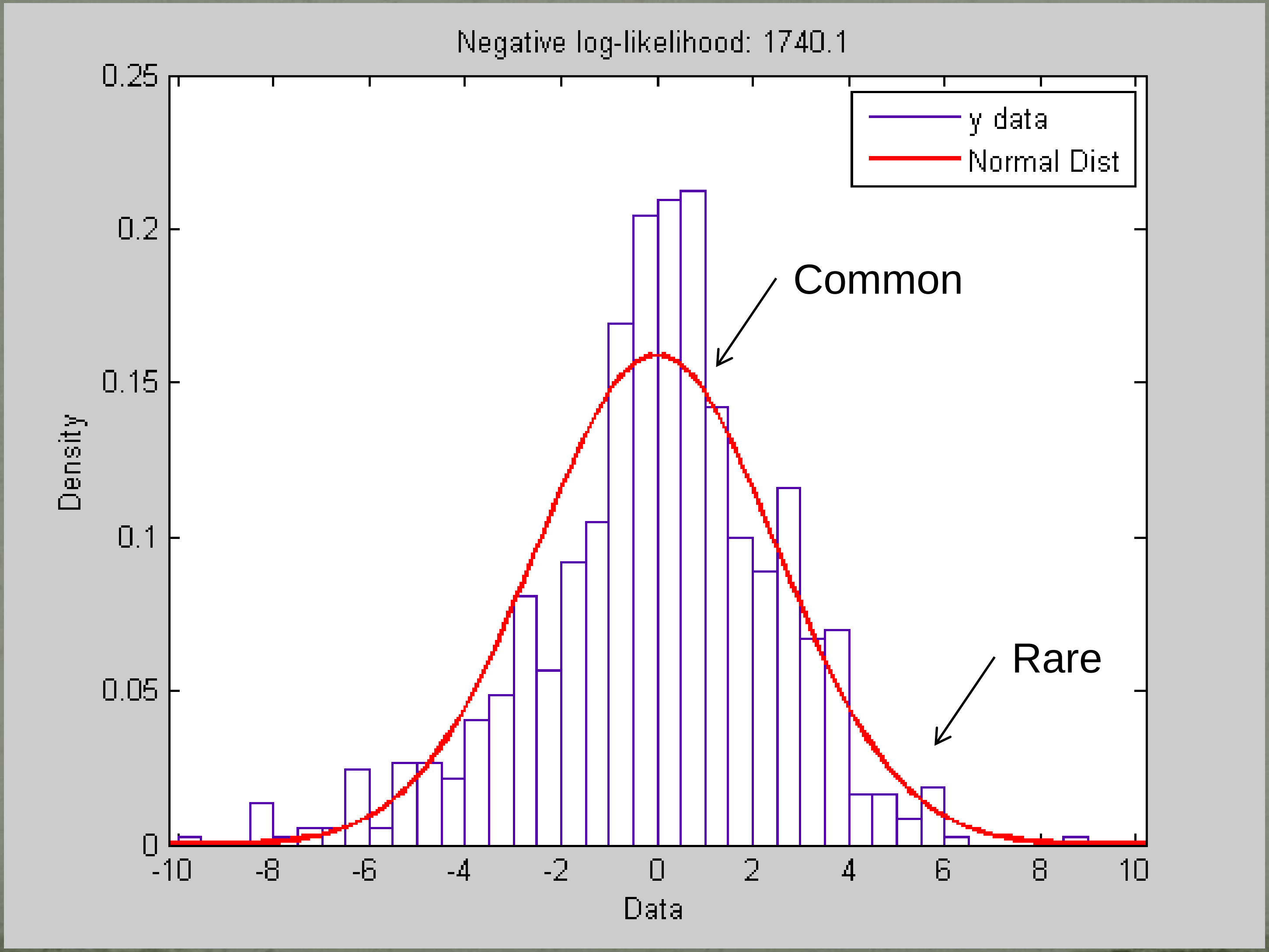
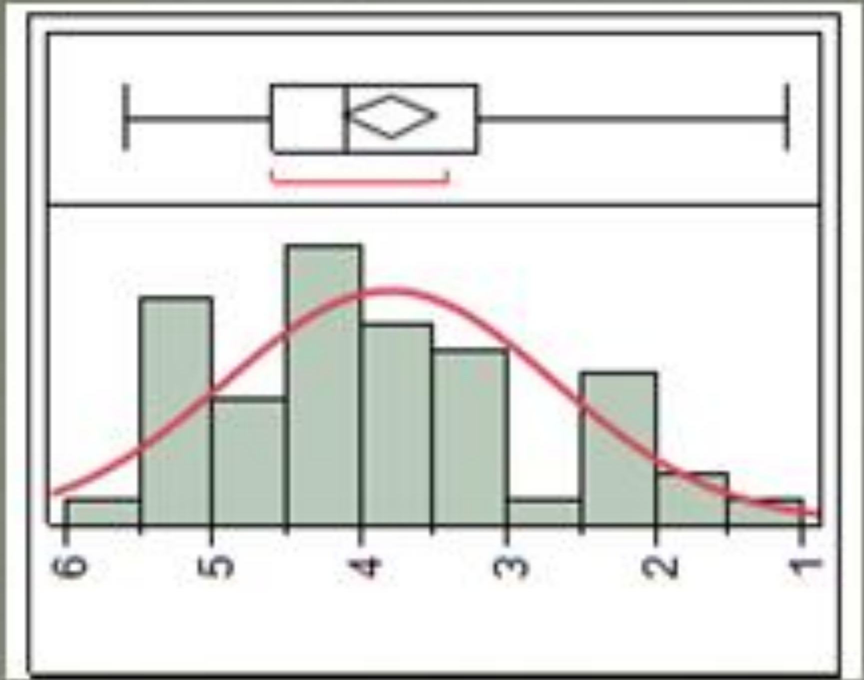
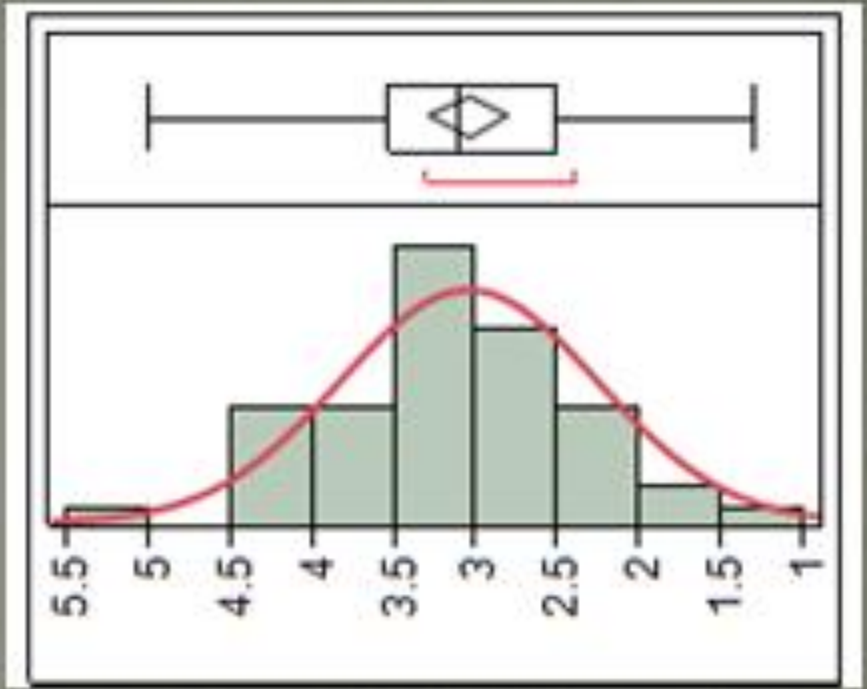
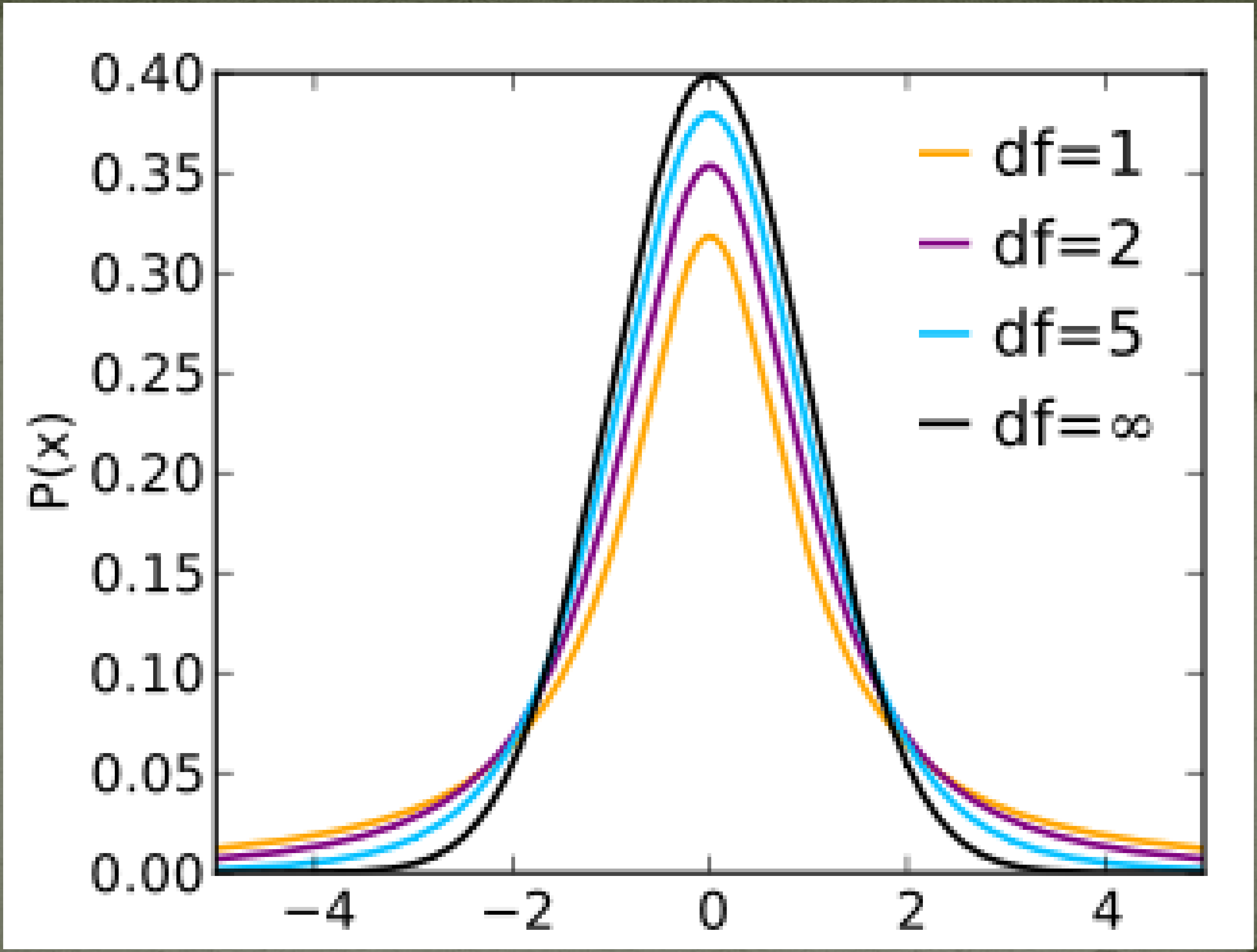




Fertilized stand DBH values



Un-Fertilized stand DBH values



t-value

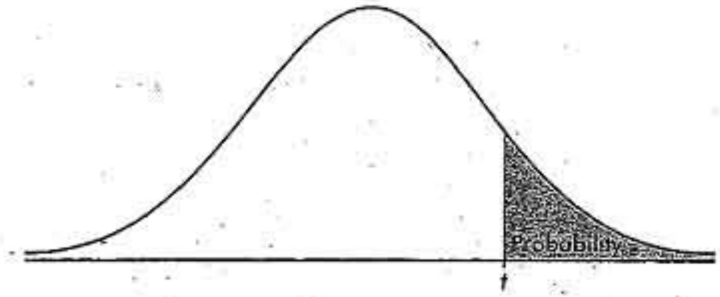
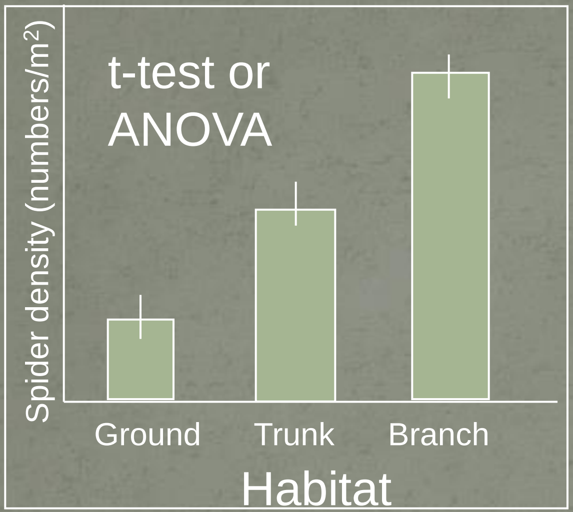


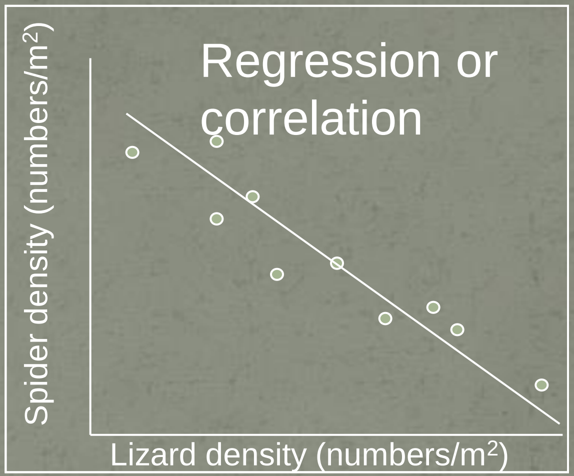
TABLE B: t-DISTRIBUTION CRITICAL VALUES

	Tail probability p											
df	.25	.20	.15	.10	.05	.025	.02	.01	.005	.0025	.001	.0005
1	1.000	1.376	1.963	3.078	6.314	12.71	15.89	31.82	63.66	127.3	318.3	636.6
2	.816	1.061	1.386	1.886	2.920	4.303	4.849	6.965	9.925	14.09	22.33	31.60
3	.765	.978	1.250	1.638	2.353	3.182	3.482	4.541	5.841	7.453	10.21	12.92
4	.741	.941	1.190	1.533	2.132	2.776	2.999	3.747	4.604	5.598	7.173	8.610
5	.727	.920	1.156	1.476	2.015	2.571	2.757	3.365	4.032	4.773	5.893	6.869
6	.718	.906	1.134	1.440	1.943	2.447	2.612	3.143	3.707	4.317	5.208	5.959
7	.711	.896	1.119	1.415	1.895	2.365	2.517	2.998	3.499	4.029	4.785	5.408
8	.706	.889	1.108	1.397	1.860	2.306	2.449	2.896	3.355	3.833	4.501	5.041
9	.703	.883	1.100	1.383	1.833	2.262	2.398	2.821	3.250	3.690	4.297	4.781
10	.700	.879	1.093	1.372	1.812	2.228	2.359	2.764	3.169	3.581	4.144	4.587
11	.697	.876	1.088	1.363	1.796	2.201	2.328	2.718	3.106	3.497	4.025	4.437
12	.695	.873	1.083	1.356	1.782	2.179	2.303	2.681	3.055	3.428	3.930	4.318
13	.694	.870	1.079	1.350	1.771	2.160	2.282	2.650	3.012	3.372	3.852	4.221
14	.692	.868	1.076	1.345	1.761	2.145	2.264	2.624	2.977	3.326	3.787	4.140
15	.691	.866	1.074	1.341	1.753	2.131	2.249	2.602	2.947	3.286	3.733	4.073
16	.690	.865	1.071	1.337	1.746	2.120	2.235	2.583	2.921	3.252	3.686	4.015
17	.689	.863	1.069	1.333	1.740	2.110	2.224	2.567	2.898	3.222	3.646	3.965
18	.688	.862	1.067	1.330	1.734	2.101	2.214	2.552	2.878	3.197	3.611	3.922
19	.688	.861	1.066	1.328	1.729	2.093	2.205	2.539	2.861	3.174	3.579	3.883
20	.687	.860	1.064	1.325	1.725	2.086	2.197	2.528	2.845	3.153	3.552	3.850
21	.686	.859	1.063	1.323	1.721	2.080	2.189	2.518	2.831	3.135	3.527	3.819
22	.686	.858	1.061	1.321	1.717	2.074	2.183	2.508	2.819	3.119	3.505	3.792
23	.685	.858	1.060	1.319	1.714	2.069	2.177	2.500	2.807	3.104	3.485	3.768
24	.685	.857	1.059	1.318	1.711	2.064	2.172	2.492	2.797	3.091	3.467	3.745
25	.684	.856	1.058	1.316	1.708	2.060	2.167	2.485	2.787	3.078	3.450	3.725
26	.684	.856	1.058	1.315	1.706	2.056	2.162	2.479	2.779	3.067	3.435	3.707
27	.684	.855	1.057	1.314	1.703	2.052	2.158	2.473	2.771	3.057	3.421	3.690
28	.683	.855	1.056	1.313	1.701	2.048	2.154	2.467	2.763	3.047	3.408	3.674
29	.683	.854	1.055	1.311	1.699	2.045	2.150	2.462	2.756	3.038	3.396	3.659
30	.683	.854	1.055	1.310	1.697	2.042	2.147	2.457	2.750	3.030	3.385	3.646
40	.681	.851	1.050	1.303	1.684	2.021	2.123	2.423	2.704	2.971	3.307	3.551
50	.679	.849	1.047	1.299	1.676	2.009	2.109	2.403	2.678	2.937	3.261	3.496

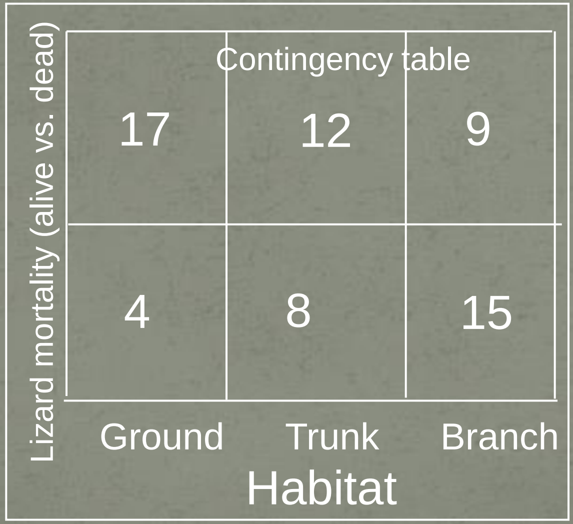
4 Basic Experiments

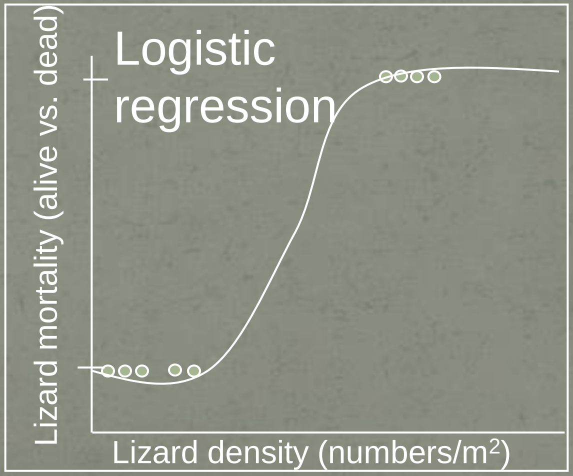
Continuous Y





Categorical Y





But others include:

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