SCIENCE AND CAUSATION

“Causation” tends to be used loosely in everyday life; has strict logical definitions.

When 2 events are observed as usually occurring together, it is common to think of one as the ‘cause’ and the other the ‘effect’.

However, this can be problematic, for instance if both occur together 1) by chance, or 2) if neither is cause nor effect, but both are the result of some other causal process.

The logic of material implication clarifies causation and defines 2 types:

1. Necessary causation.

The occurrence of an effect (E) guarantees that a condition (C) is present.

$$E \Rightarrow C. \text{ (If E then C)}$$

Equivalently $\sim C \Rightarrow \sim E$

If the condition is absent, the effect must be absent as well (so the condition is *necessary* for the effect).

However, nothing can be inferred about the effect E in the presence of C; it may or may not occur.

Example: **C=light E=photsynthesis**

“Light is a necessary cause of photosynthesis”

If E occurs, then C must be present;

likewise, if C does not occur, E cannot be present.

However, if C occurs, E may or may not occur (there may be other conditions for E to occur)

2. Sufficient causation

Logically stronger than necessary causation. Specifies that C alone ensures that E occurs

$$C \Rightarrow E.$$

The occurrence of C guarantees the effect E. Likewise

$$\sim E \Rightarrow \sim C$$

If the effect does not occur, the condition C cannot be present.

Example:

If it is a bird (C) then it lays eggs (E).

If it does not lay eggs, it cannot be a bird.

$$C \Rightarrow E.$$

$$\sim E \Rightarrow \sim C$$

Note that the reverse does not work in this case

$E \Rightarrow C$. If it lays eggs it is a bird.

I.e, being a bird is a <u>sufficient</u> but <u>not a necessary</u> condition for laying eggs.

That is

Clearly, $E \Rightarrow C$ (if it lays eggs it is a birds) and thus $\sim C \Rightarrow \sim E$ (if it isn't a bird, it doesn't lay eggs) doesn't hold: the absence of the condition (being a bird) does not imply that the animal does not lay eggs (counterexample = fish, reptiles, amphibians).

The strongest possible causation is <u>necessary and sufficient causation</u>. "If and only if C, then E"

Examples:

$Y=\sqrt{X}$ if and only if $X=Y^2$.

Vertebrates are mammals if, and only if, they lactate and have hair

Note that the above are special cases of logical syllogisms

Premiss 1
Premiss 2
Premiss n
____.___
Conclusion

Valid forms (conclusions are always true if the premisses are true):

Modus tollens (denying the consequent)

$$\begin{array}{c} A \Rightarrow \sim B \\ \sim B \\ \hline \therefore \sim A \end{array}$$

Modus ponens (affirming the antecedent)

$$\begin{array}{l} A \Rightarrow B \\ A \\ \hline \therefore\ B \end{array}$$

Invalid forms: affirming the consequent

$$\begin{array}{l} A \Rightarrow B \\ B \\ \hline \therefore\ A \end{array}$$

denying the antecedent

$$\begin{array}{l} A \Rightarrow B \\ \sim A \\ \hline \therefore\ \sim B \end{array}$$

ROLE OF LOGIC IN SCIENTIFIC EXPERIMENTS

Experimental treatment: seeks to investigate whether sufficiency of condition: does E occur in the presence of C

$$C \Rightarrow E$$

Under rules of logic, this can only be falsified (i.e., by observing ~E we would infer ~C).

Controls allow us to investigate if the absence of C results in the absence of E, thus establishing necessity. Under necessity we have

$$\sim C \Rightarrow \sim E$$

so if we observe E when ~C (absence of the condition under control) is the condition, then we know that the condition cannot be necessary.

(Note that with A=~C and B=~E we get modus tollens)

DEVELOPING AND TESTING BIOLOGICAL HYPOTHESES

1. State a theory {T}

2. Develop a hypothesis H,that asserts a claim about relationships among components of the theory.

When added to a theory, it renders the theory potentially inconsistent, or potentially false.

$$\{T\}+H$$

Competing hypotheses can be rendered as

$$\{T_0\}+H$$

and

$$\{T_0\}+H_0$$

where $\{T_0\}+H_0$ represents the theory before amendment by the new H (and is [may be] more complex).

3. Deduce observable conclusions from the amended theory

$$\{T\}+H \Rightarrow P$$

P=potentially observable predictions

4. Make observations under field or experimental conditions--- 0

5. Compare predictions against data

Example: additive and compensatory mortality

{T}= general theory of population regulation
H= hypothesis of compensation in waterfowl

{T}+H ⇒ P1 no relationship between survival rate and hunting mortality up to a threshold

{T}+H ⇒ P2 negative relationship between hunting and nonhunting mortality
{T}+H ⇒ P3 Positive relationship between hunting mortality and populations size.

Each potentially is comparable to data under observational or experimental conditions.

Note that is some cases P corresponds to what we might think of as the statistical null; in others the alternative.

INDUCTIVE LOGIC IN SCIENTIFIC METHOD

Above rules of deductive logical always yield valid conclusions when premisses are true.

By contrast, an inductive argument can have true premises without a necessarily true conclusion. Consider the following inductive argument:

P1: I have taken blood samples of 10,000 animals from a population of 100,000 foxes

P2:Every sample was negative for rabies

C: Therefore, there is no rabies in the population

Both of the premises may be completely true in this argument, but the conclusion false (that is cannot be stated with certainty).

The best we can do with an inductive argument is to say that the conclusion is *probable* given that the premises are true.

We will use probability and statistical likelihood as measures of 'probable'.

Natural variation (and sampling error) can lead to the rejection of a hypothesis that otherwise would be seen as appropriate, just as it can support acceptance of an inappropriate hypothesis.

Biological investigation is by its very nature open to the risk of incorrect inference, which can decline as evidence accumulates but never vanishes.

It is the role of probability and statistics in biological science to characterize and account for this risk.

METHODS OF SCIENCE

1. Hypothetico- deductive

--null and alternative hypotheses
---seeks disconfirmation of predicted response

Difficulties: Based on assumptions of a single operative hypothesis—competitors get eliminated one at a time

Assymetry of null and alternative (‘acceptance’ of null is not strong ‘proof’ of alternatives).

2. Complementary hypotheses

Wildlife science is replete with examples of complementary factors interacting in complex ways to produce observed effects.

All factors may be operating simultaneously, playing important but unequal roles in influencing population dynamics.

Paradigm of single hypothesis may not be useful.

- **Leads to suggestion by some that**
- **Emphasis be on identifying plausible mechanisms and evaluating their relative contributions.**
- **De-emphasize Ho testing (see Johnson, D. H. JWM 63:763-772.)**

    - **STATISTICAL HYPOTHESES ARE NOT THE SAME AS BIOLOGICAL HYPOTHESES!!**

- **Emphasize model building and prediction.**
- **Leads naturally to adaptive resource management**
    - **Model(competing Hs)------> objective**
    - **Conduct management to reach objective averaging over Hs**
    - **Observe outcome vs predictions under competing H’s**
    - **Update model accordingly and repeat**