## THE BRADFORD HILL CRITERIA

A correlation between X and Y does not imply that X causes Y. But when *is* it reasonable to conclude that X causes Y? In *epidemiology* and *law*, the Bradford Hill criteria are often used to assess the issue.

**WARNING**: None of the criteria are *necessary* for justifying that *X* causes *Y* (although 3 is normally necessary). Nor are the criteria individually or jointly *sufficient*. Ultimately, as Susan Haack says, the plausibility of someone's causal hypothesis "depends in part on how tightly the components of the whole body of their [theory] interlock, and in part on how much of the relevant information it includes" (p. 263). Bradford Hill also stressed that there is no clear algorithm for detecting cause and effect. The best we can do is go with the most justified theory, relative to the current state of evidence.

## <u>The Criteria</u>

If there is evidence of a positive association between *X* and *Y*, then the following count as evidence that *X* causes *Y*:

- 1. **Strength of association**: A strong association is observed between *X* and *Y*. But note that *X* and *Y* could be causally related even if they are not strongly associated. (Few people exposed to rat urine develop Weil's disease, but the association is still causal.)
- 2. **Reproducibility**: A similar strength of association between *X* and *Y* is observed in a variety of different studies (e.g., in different places, with different samples).
- 3. Temporality: X occurs before Y.
- 4. **Dose-dependence** (epidemiology): A greater incidence of *X* usually leads to a higher incidence of *Y* (e.g., the greater the exposure to ionizing radiation, the higher the risk of malignancy). Also, as this implies, a lower incidence of *X* usually leads to a lower incidence of *Y*.
- 5. **Experiment**: Testing reveals that if *X* is decreased or absent, *Y* is reduced as well (e.g., social distancing is associated with a decrease in COVID-19 cases)
- 6. **Specificity**: A strong association between *X* and *Y* is observed when localized to a particular, time, place, population, etc. (e.g., there is an increase in leukemia cases in a small town after a chemical factory is built nearby). High specificity suggests a lower chance that the association is mere coincidence.
- 7. Analogy: X and Y are similar to W and Z, respectively, and there is strong evidence that W causes Z (e.g., when one class of medication is known to produce an effect, another agent of that class likely produces a similar effect).
- 8. **Coherence**: The causal hypothesis fits with previously established facts (This criterion is not met, e.g., if a study finds higher rates of lung cancer in men while there is no antecedent biological data to support it).
- 9. **Biologic plausibility**: A causal relationship between *X* and *Y* is plausibly explained by known biological mechanisms (e.g., DNA damage from cigarette smoke causes cancer in the lung).

## Contrast with "Mill's Methods"

Critical thinking textbooks often cover "Mill's Methods" for determining cause and effect, and not the Bradford Hill criteria. However, Mill was writing in the 19<sup>th</sup> century, and his methods seem a bit less refined.

For example, instead of observing the strength of association between variables X and Y, he spoke instead about observing whether Y occurs when X is present, and observing whether Y does not occur when X is absent. He called these the method of "agreement" and the method of "difference," respectively. If such things are observed, that is surely relevant to whether X causes Y. But it is more useful to look for the *strength* of association between X and Y: *How often* does Y occur when X is present? *How often* does Y not occur when X is absent?

Note also that this concerns only an association between *discrete* variables—variables that are either "all or nothing." (Either you are pregnant or not.) But in other cases, the variables are *continuous*—they come in degrees. Thus, your blood may be more or less high in iron, and we can measure the degree to which it is high in iron by the amount of red meat you eat.

With continuous variables, Mill's methods of agreement and of difference do not apply. After all, we would not just be looking at whether iron is present/absent and whether you eat some meat versus no meat. But strength of association is still applicable. For example, we might observe iron levels increased an average of 10% when 20% more red meat is eaten. The percentage increase is an indication of the strength of the association observed, and it of course lends support to red meat consumption *causing* increased iron levels. That, in turn, illustrates "dose dependence" criterion mentioned by Bradford Hill.

In fairness, Mill was aware of this sort of thing as well; he described observations of "concomitant variation" between variables. Even so, "strength of association" is more readily quantifiable. Plus, Bradford Hill offers additional, useful criteria which help us judge whether *X* is causally related to *Y*.