USE OF HYPOTHESES IN THE SCIENCE AND INFORMATION DIVISION

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"The hypothesis is the principal intellectual instrument in research" - WIB Beveridge

The following comments are presented to stimulate discussion amongst science staff in SID on the important topics of clear formulation of hypotheses, the rationale behind the null hypothesis, and the significance of testability, objectivity and rigour.

Hypothesis literally means 'lesser proposition', embodying the ideas of tentativeness and uncertainty. Hypotheses represent mental maps of how we think aspects of nature work. They can vary in quality from the pedestrian to the completely novel, a new way of looking at some aspect of the world. Hypotheses are important because if they are testable they guide our collection of data. This serves to minimize expensive and time-consuming gathering of inconclusive or irrelevant data.

Generation of hypotheses is subjective; where highly so it may represent a profoundly imaginative and truly creative act. This is the bold conjecture that tends to elate (the "Eureka" phenomenon). The testing of hypotheses, on the other hand, has to be truly objective. Who would wish to waste their time continuing to embrace an hypothesis without trying to find out whether its basis is true? Moreover, if we don't attempt to find out its scope and weaknesses, our professional competitors *will*!

Over the last decade or so it has become fashionable for scientists and philosophers of science to claim that there is no single method of science. I agree with this in the sense that doing science is not like following a recipe to bake a cake, but in a more profound sense the claim seems wrong. Several centuries of scientific endeavour have shown that the so-called hypothetico-deductive method of discovery is highly effective - it works; it exposes error; it saves time and money; and it minimizes dogmatism. Moreover, it is widely recognized to have a logically impeccable foundation thanks to the attention given to it by illustrious philosophers such as Whewell (last century) and Popper (this century).

The essence of Popper's viewpoint (as given in, for example, his book *Conjectures and Refutations*) is:

- Take note that truth is not manifest and is not easy to come by. Imagination, trial and error, the gradual discovery of our prejudices, and critical discussion are essential ingredients in the search for truth.
- Distinguish science from other intellectual endeavours by the criterion of empirical disproof - a scientific hypothesis must be able (at least in principle) to be found wrong by experiment or observation.
- Comprehend the essential idea or concept - arguments about words and their meanings become insignificant and distracting.
- Do not evade criticism or look for verifications or confirmations but instead seek crucial tests or refutations, ie tests which could refute the hypothesis under test.
- Accept that an hypothesis can never be established. No test is final or conclusive.
- Realize that the more an hypothesis forbids, the more it tells us. Thus the hypothesis All swan species are white would if true convey more than the hypothesis Some (or most) swan species are white.
- Be self-critical. Ask 'under what conditions would I admit that my hypothesis is untenable?' ie what conceivable facts would I accept as refuting or falsifying my hypothesis?
- Recognize that progress in science consists of moving towards hypotheses and theories which explain more and more. Scientific progress is not the accumulation of observations but the overthrow of less adequate hypotheses by better ones (ie hypotheses of greater content).
- Realize that there is no induction, because universal theories are not deducible from singular statements. But they may be refuted by singular statements, since they may clash with descriptions of observable facts.
- Accept that our knowledge grows through trial and error. Therefore, consciously search for our errors and eliminate them.
- Realize from the history of science that there have been many more incorrect hypotheses than correct ones.
- Be objective - ie justify your preference for a hypothesis on the basis that it has stood up to refutation and criticism better than its competitors, and certainly not on the basis that it is your hypothesis or that you would like it to be true or that you think it will be good for society!

The null hypothesis (ie that X and Y are not different or that A does not cause B) is of great importance. In statistical analysis, one computes a statistic and the corresponding probability of a more extreme value (as in a t-test, for example). One tries to strike a balance between committing so-called type I and type II errors (ie falsely rejecting a true null hypothesis vs failing to reject a false null hypothesis). A type II error perpetuates ignorance whereas a type I error results in a false positive; this probably accounts for the attention given by scientists to levels of significance (usually $a = 0.05$) rather than statistical power (β).

In logic, only one counter example suffices to disprove a null hypothesis, whereas thousands of confirmatory examples can never prove an hypothesis, eg contrast 'The swans of Europe and Australia do not differ in colour' with "All swans are white'. Moreover, the second hypothesis is confirmed by seeing a white swan and logically is equivalent to "All entities which are not white are not swans". Seeing a sparrow therefore, paradoxically, confirms that all swans are white!, as made by someone living in Europe. Likewise, it is logically more defensible to propose and test "Prescribed burning of jarrah forest in spring does not spread *Phytophthora* fungus"(A) rather than "Prescribed burning of jarrah forest in spring causes the spread of *Phytophthora* fungus"(B). If the evidence collected does not refute (A), then we do not need to consider (B). It does not make logical sense to not formulate (A) and instead to proceed directly to attempting to test (B).

This initial formulation and testing of the null hypothesis as a foundation of scientific inquiry seems to be analogous to the presumption in criminal law of innocence until guilt is proven. In our preparation of Science Project Plans, should we state explicitly the null hypothesis as part of the Aim of the project?

I would be most interested to hear other's views on the above and on any related issues, including:

- How are hypotheses used in taxonomic studies?
- What hypothesis is being tested in monitoring?
- Is there a more intellectually superior instrument than the hypothesis in research?