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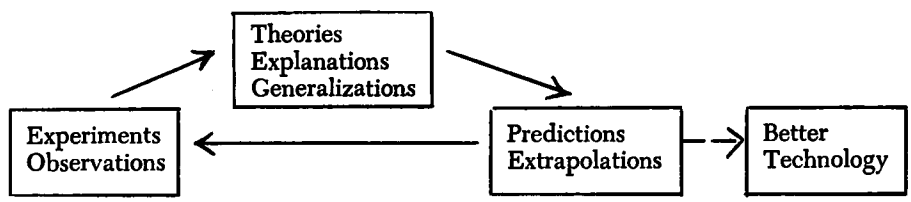
COMPLETING THE UPWARD SPIRAL

Scientific knowledge is constructed from: (a) experiments carefully planned to yield reproducible and meaningful observations, (b) theories explaining the observations and leading to fruitful generalizations, and (c) predictions of new phenomenon that can be observed. The Scientific Method is accomplished by designing and executing experiments to test the existing theories and predictions, which leads to increased confidence or modifications. Since this closed circle leads to ever increasing scientific knowledge and the power to devise more effective technologies, it would be appropriate to name it the Upward Spiral.



Experimental observations do not become scientific knowledge until they are explained and generalized by theories. Never accept an experimental result until it is explained by a good theory. An unexpected experimental result could mean a new phenomenon and the upset of an old theory, or it could mean poor execution and inappropriate interpretation. A recent example is the experimental observation that an "egg-yolk" catalyst, where the active platinum is deposited towards the interior of a catalyst pellet, was found to be more active in oxidation of carbon monoxide than the traditional "egg-shell" catalysts, where platinum is deposited at the exterior. This observation seemed to be against the well-known theory (based on positive order kinetics) that diffusion length should be minimized for better catalyst effectiveness. This experimental observation was simply not believed, until the arrival of a new theory that showed for a negative order kinetics, increased diffusion length can lead to high effectiveness.

Theory without experimental foundation, and prediction without verification, are also regarded with skepticism. Any theory and prediction must make simplifications to concentrate on a few major factors, and may thereby leave out other important factors. A theory that is verified by a limited range of experimental observations continues to be jeopardized by every new observation. Newton's theory of mechanics endured for two centuries before it became inadequate to deal with motion at the speed of light, and it was replaced with Einstein's theory. A useful theory must lead to predictions that can be tested by future experiments, and should lead to better engineering designs and operations.

In principle, this upward spiral may be carried by different specialists in widely separated geographic regions, if each participant would do his share to understand and to communicate effectively to the other participants. A theoretical paper is not complete if it does not predict additional phenomena that can be tested. To write such a paper, the theorist needs to appreciate what observations need explanation, which experiments can be performed, and which predictions are important to those in engineering design and operations. An experimental paper is incomplete if the results do not gratify or challenge the theorists. To write such a paper, the experimenter must know the existing theories and predictions, and must design a set of experiments to test them.

Current research journals contain many theoretical papers that make no testable predictions, and experimental papers that lead to no useful generalizations. They represent many promising ideas and observations that would vanish into dusty archives. We have to build better links to the other participants, so that our research will be utilized and carried forward by others as part of the vitalizing upward spiral.

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