# PHILOSOPHY OF MODELING

## Overview

- Modeling
- Scientific method
- Karl Popper
- Scientific method
- Problems in modeling
- Stages in model development
- Model complexity
- Model complexity
- Conclusions

*"After all, a mathematical model is only a set of equations. Its link to reality is via the physical properties data of the system it is intended to simulate. Its success at simulation is not guaranteed but must be proven by suitable validation.....The basic dilemma in the process of validation may be stated in the following manner: a mathematical analogue can be validated only in a given number of known situations. Thus, no perfect validation is possible." (sic, page 238).*
***Panjabi (1979)***

# MODELING

**A model** is a representation of the essential aspects of a system (e.g. muscle; human body), in a usable form (e.g. mathematical equations).

**Advantages**: Strict control of variables possible.

**Limitations**: Artificial representation (too simple).

Standard analysis of human movement using models, for example body segments are assumed rigid, which is effectively a model.

# SCIENTIFIC METHOD

**Theory** – principle suggested to explain observed facts or phenomena

**Hypothesis** – provisional explanation of observed facts.

## Is a theory scientific?

1. Assume the statement is wrong.
2. Imagine a result which would then prove it wrong.

If you cannot complete both steps you must conclude that the statement is not scientific.

# KARL POPPER (1902 - 1994)

Concept of falsification as process of advancing science.

**Hypothesis**: Gold is soluble in hydrochloric acid.
**Scientific**: Yes, though false.
**Why?**: Because we can eliminate it if it is false.

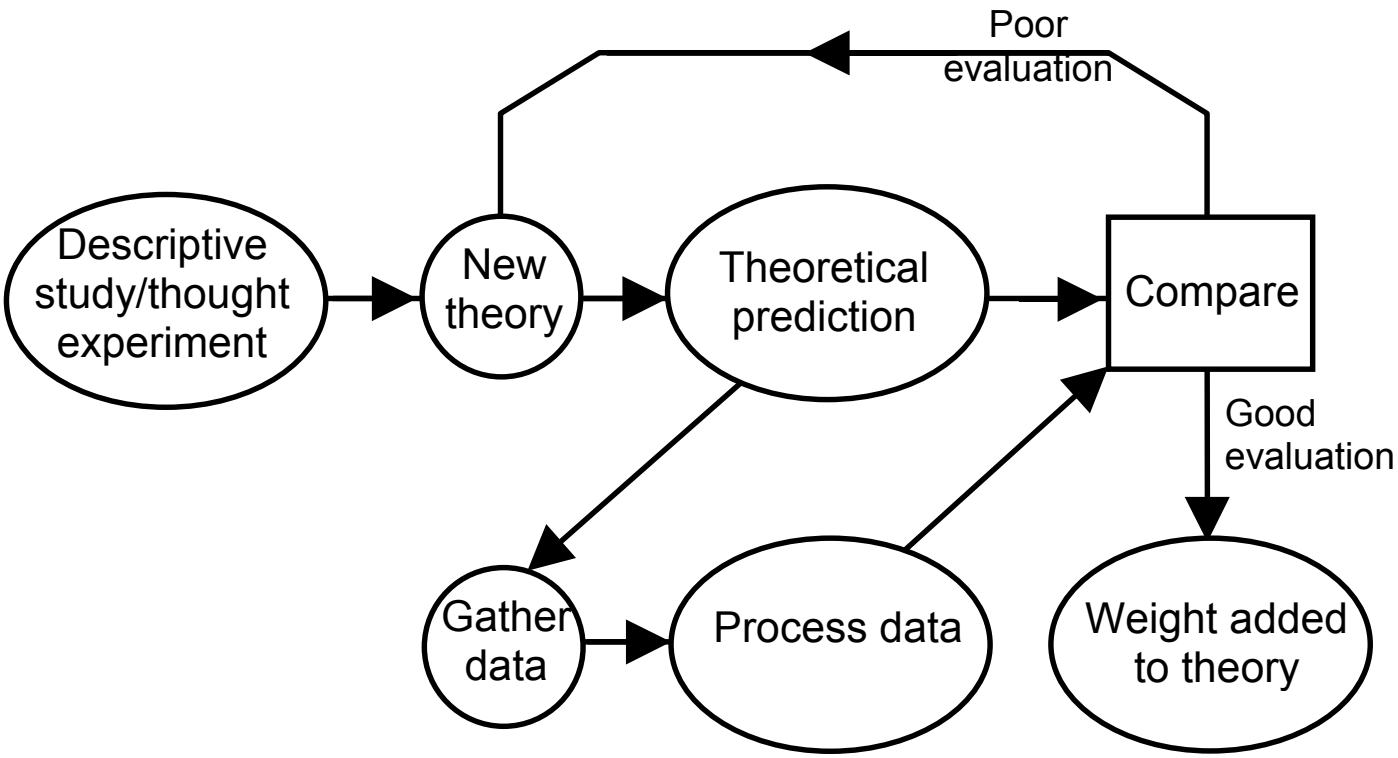
**Hypothesis**: Some homeopathic medicine do work.
**Scientific**: No, though possibly true.
**Why?**: It is unscientific because even if it were false we could not get rid of it by confronting it with an observation/report that contradicted it.

Positive Support for theories is unobtainable, accept in the sense that you have failed to falsify it. Science in this view does not offer proof.

## *Is falsification itself falsifiable?*

You can falsify a theory, but not a rule of method (rules are open to other types of criticism).

# SCIENTIFIC METHOD




A theory should lead to some prediction which can be tested by experiment. Comparison of prediction with experimental results should lead to either: rejection of theory; modification of theory; (temporary) acceptance of theory.

(Theories are not proved, but fail to be falsified.)

# PROBLEMS IN MODELING

- Model Formulation
- Parameter Determination
- Complexity
- Validation

# STAGES IN MODEL DEVELOPMENT

1. ***Definition of the problem***.

2. ***Statement of assumptions***.

3. ***Formulation of system equations***.

4. ***Solution of system***.

5. ***Validation***.

6. ***Simulations***.

# Stage 1. - Definition of the Problem

## Questions

- Is there a question being phrased which can be answered?
- Is it suitable for modeling?

## Solutions

- Follow scientific method…….

# Stage 2. - Statement of Assumptions

## Questions

- Are assumptions reasonable?
- Will model once formulated indicate which assumptions should not have been ignored?
- Could assumptions be incorporated into model if necessary?
- Have others made the same assumption?

## Solutions

- Only normally possible once model has been formulated and tested.
- Problem of compensating errors.

# Stage 3. - Formulation of System Equations

## Questions

- Are the equations correct?
- Could they be formulated in a more compact form?
- Are the equations in a form readily programmed on a computer?

## Solutions

- Computerized equation generation (e.g. MAPLE, DADS)
- Kanes method preferred to Newtons.
- Automatically generate computer code.
- Get somebody else to check them.

# Stage 4. - Solution of System.

## Questions

- Is program coded correctly?
- Can input parameters be determined?

## Solutions

- Run some trial data
- Model parameters are often a function of model complexity which is considered later.

# Stage 5. - Validation

## Questions

- What would be suitable prediction accuracy?
- Are predictions of model sufficiently accurate?
- What extrapolations from model are realistic?

## Validity

"After all, a mathematical model is only a set of equations. Its link to reality is via the physical properties data of the system it is intended to simulate. Its success at simulation is not guaranteed but must be proven by suitable validation.....The basic dilemma in the process of validation may be stated in the following manner: a mathematical analogue can be validated only in a given number of known situations. Thus, no perfect validation is possible."
(sic, Panjabi, 1979).

Some would argue that model evaluation is a better term than model validation.

# Stage 6. - Simulations

## Questions

- What extrapolations beyond validation are realistic?

## Solution

- Maybe there is some art as well as science in it.

# MODEL COMPLEXITY

| | SIMPLE MODELS | COMPLEX MODELS |
|---|---|---|
| 1 | Simple to formulate | Complex to formulate (therefore prone to errors) |
| 2 | Simulation not too time consuming | Simulations can be time consuming |
| 3 | Parameters are few | Many model parameters |
| 4 | Parameters easy to determine | Parameter determination a problem |
| 5 | Easy to interpret | Output hard to interpret |

# MODEL COMPLEXITY

General principle in selecting a model is expressed by ***Ockhams Razor*** which states***:-***

***"It would be futile to accomplish with a greater number of things what can be accomplished with fewer."***
William of Ockham (1290-1349)

Which in essence means select simplest possible model to describe a process as long as it is valid.

By creating a parsimonious model you are making an assumption which should be acknowledged.

In formulating the model you can have two starting points:-

1. Simplest model, and add components as required (e.g. Alexander, 1992)
2. Start with a complex model and remove components until simplest valid model is achieved.

# CONCLUSIONS

## Why model?

- Permits total control
- Forces recognition of essential elements of system

## Safety measures

- Fit model to task
- Model must be validated
- Careful of extrapolation
- Ockhams razor

# REVIEW QUESTIONS

**1)** Describe the cyclical process of the scientific method.

**2)** What are the phases in the development of a model?

**3)** What are the advantages of doing experimental work over modeling work?

**4)** What are the relative merits of a complex and simple models?

**5)** Explain the basic dilemma when attempting to validate a model.

**6)** How can you test whether a statement is scientific?