# Research

The Science of Design

Goals:

- What are the logical principles needed to make design into a science?

- Why did Herbert Simon write this paper?

- What impact does this theory have on design?

Herbert Simon (1916-2001)

- The Science of the Artificial (1969)

- "...his research ranged across the fields of cognitive psychology, cognitive science, computer science, public administration, economics, management, philosophy of science, sociology, and political science, **unified by studies of decision-making**." (Wikipedia)
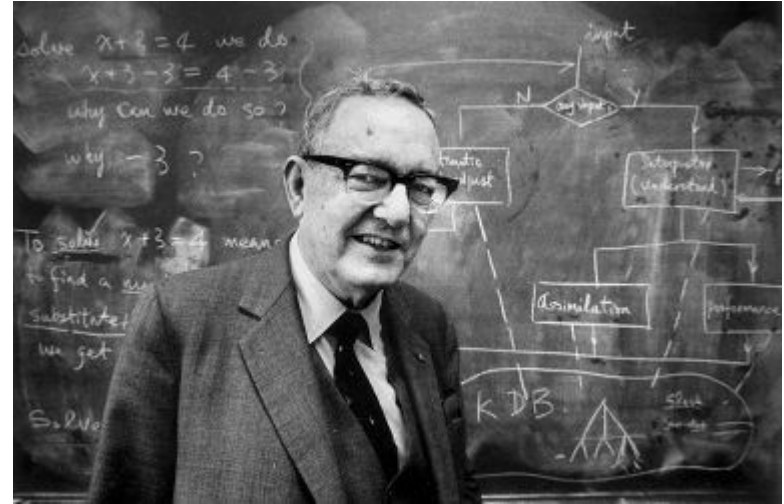
Herbert Simon

What does it mean for something to be a science?

"...academic respectability calls for subject matter that is intellectually tough, analytic, formalizable, and teachable..." (pg. 130)

"...academic respectability calls for subject matter that is intellectually tough, analytic, formalizable, and teachable. In the past much, if not most, of what we knew about design and about the artificial sciences was intellectually soft, intuitive, informal, and cookbooky." (pg. 130)

"It is the thesis of this chapter that such a science of design not only is possible but is actually emerging at the present time."

Artificial and Natural Science

Artificial and Natural Science

- <u>Natural Science</u>: understanding natural phenomena of the world - how things are and how they work.
  - Biology, Chemistry, Physics, etc

- <u>Artificial Science:</u> adapting things to meet desired properties.
  - "Design, on the other hand, is concerned with how things ought to be, with devising artifacts to attain goals" (pg 133)

Design: "Everyone designs who devises courses of action aimed at changing existing situations into prefered ones." (pg. 129)

Logic of Design - Optimization Methods

- Command Variables: Means
- Fixed Parameters: Laws
- Constraints: Ends
- Utility function: Ends
- Problem: Given the constraints and fixed parameters, find the values of the command variables that maximize utility

Logic of Design - Lunch

Command variables	Quantities of foods
Fixed parameters	Prices of foods
	Nutritional content
Constraints	Nutritional requirements
Utility function	- Cost of diet

"The problem is to select the quantities of foods that will meet the nutritional requirements and side conditions at the given prices for the lowest cost." (pg 136)

Logic of Design - Class Scheduling

Command variables	Quantities of foods
Fixed parameters	Prices of foods
	Nutritional content
Constraints	Nutritional requirements
Utility function	- Cost of diet

Optimization vs Satisficing

- Optimization:
  - Linear Programming / Dantzig's Simplex algorithm (John)
  - Open-Heart Surgery (Stephanie)
- Satisficing:
  - Rental Service (Daniel)
  - Finding a city to live in (Enhao)

Traveling Salesman

- What is the most efficient path the "salesman" can take through each of the n "cities"?

- "Rather than keep our salesman at home, we shall prefer of course to find a satisfactory, if not optimal, routing for him." (pg 139)
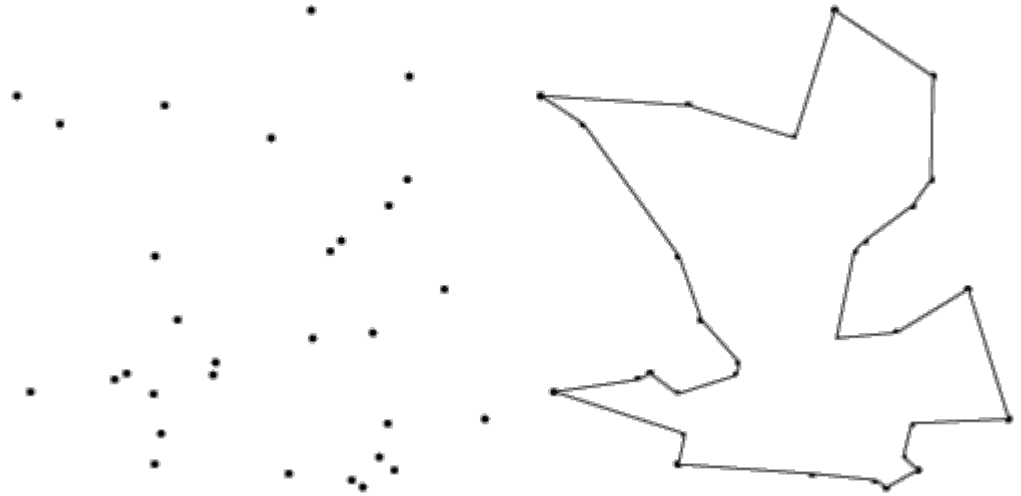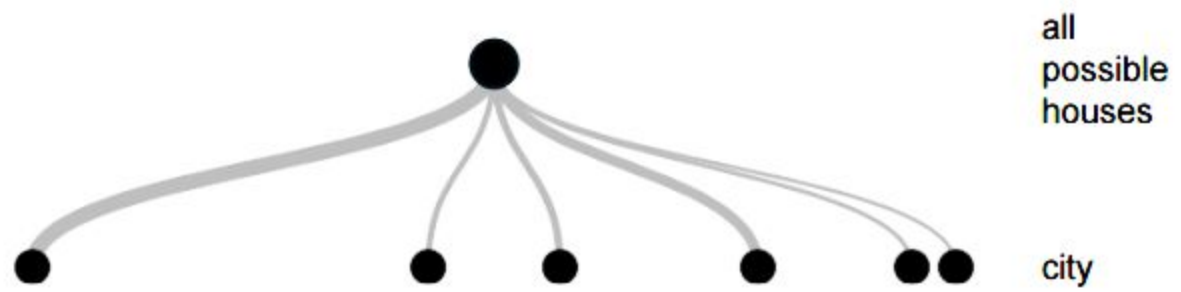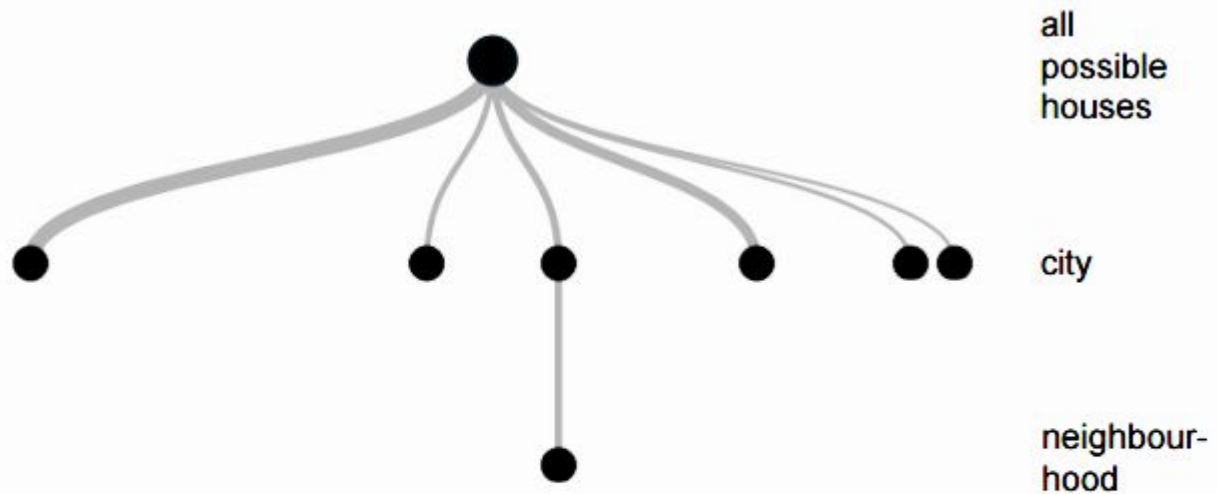
"Bounded Rationality"
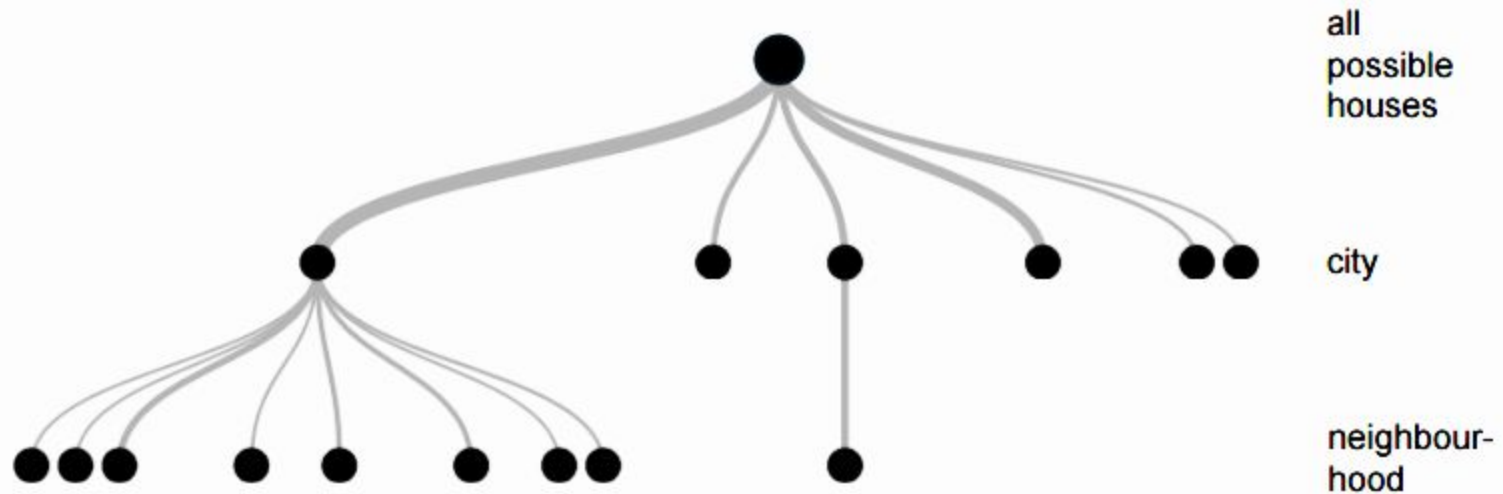
What are some strategies for satisficing?

Allocation of resources

all
possible
houses

all
possible
houses

city

all
possible
houses

city

neighbour-
hood

all
possible
houses

city

neighbour-
hood

all
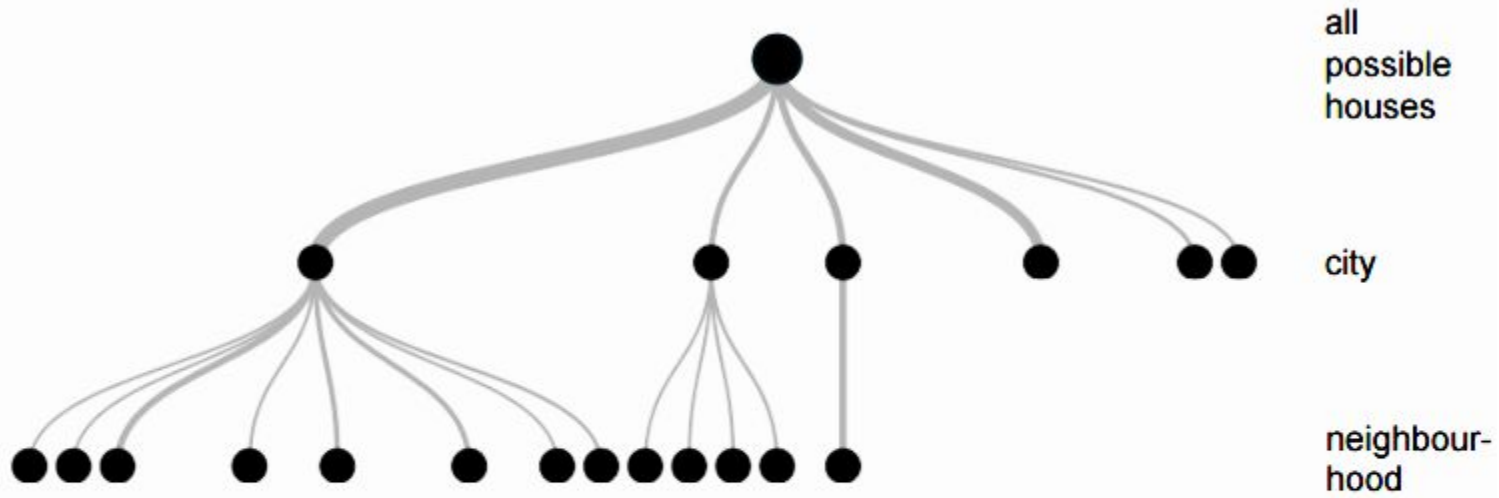possible
houses

city

neighbour-
hood

all
possible
houses

city

neighbour-
hood

specific
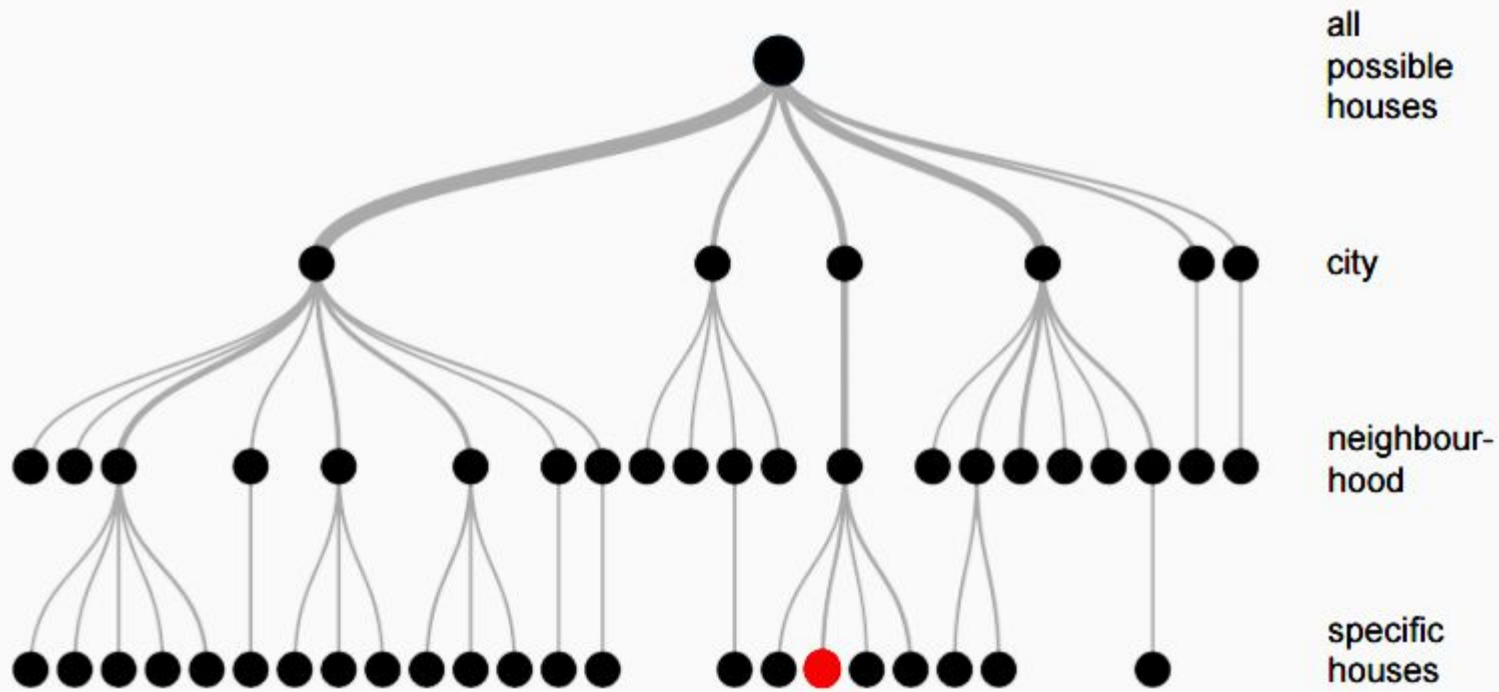houses

Process as a determinant of style

- Inside -> Out vs Outside -> In
- Concrete Logic -> Qualitative Analysis

The Representation of Design

Questions

Does this framework reflect your own design process?

Questions

Is this theory relevant to design researchers today?

Questions

What motivated Simon to write this paper?

Transforming the Paradigm (Pasteur's Quadrant)

What was the paradigm?
- Basic research

What was the paradigm?
- Basic research

- Scientific research aimed to improve scientific theories for improved understanding or prediction of natural or other phenomena

- Aims to improve fundamental knowledge about the world

- may not be immediately utilized but nonetheless form the basis of progress and development in different fields

What was the paradigm?
- Applied research

What was the paradigm?
- Applied research

- Research that applies existing scientific knowledge to develop more practical applications, like technology or inventions

- Influenced by the consideration of use

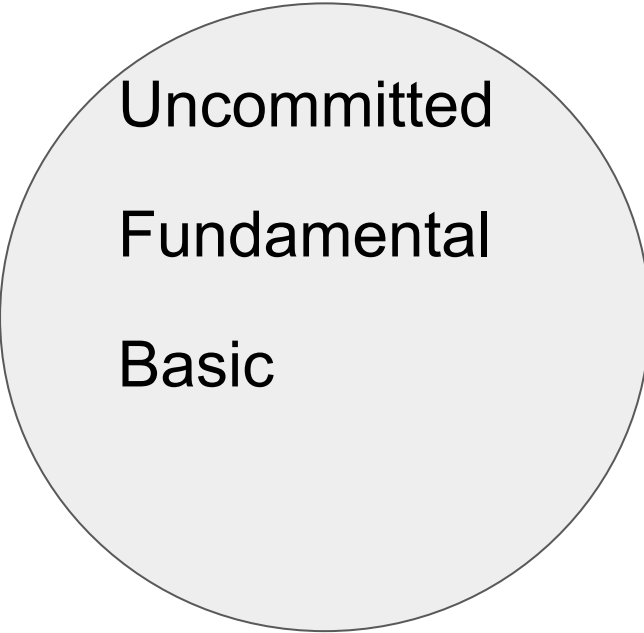# What was the paradigm?

Uncommitted

Fundamental

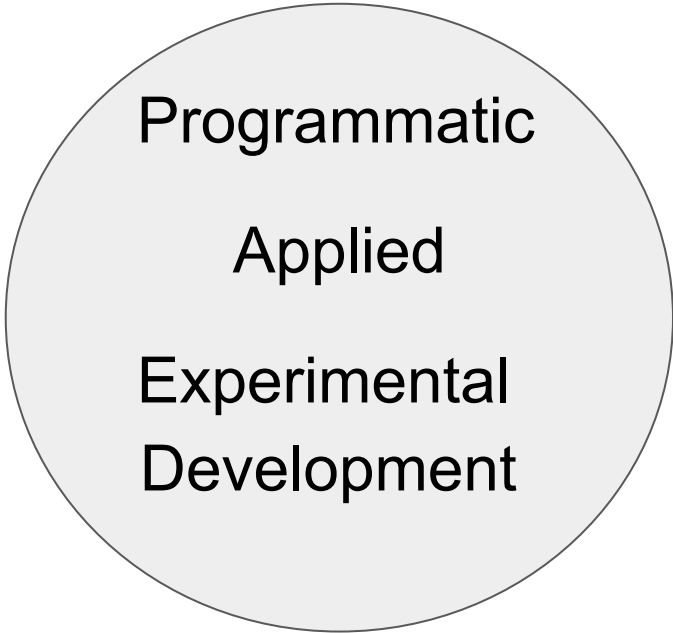Basic

Programmatic

Applied

Experimental
Development

What was the paradigm?

Uncommitted

Fundamental

Basic

Posive basic research

oriented basic

mission oriented

Programmatic

Applied

Experimental
Development

What was the paradigm?

Oriented basic - methods of research are fundamental by nature but influenced by application

Experimental Development - use of results of fundamental and applied research directed to introduction to useful materials, devices, products, systems and processes
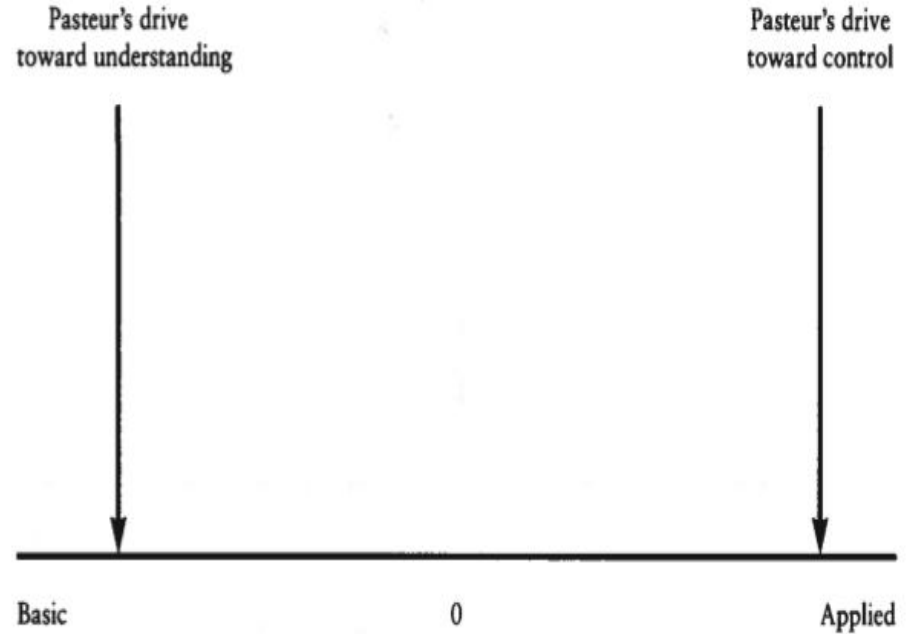
Discussion

Turn to your partner and discuss
(2-3 mins)

What are the issues that you see with
this representation?

How can you improve this diagram?

Specific practical aim or objective

Experimental development

Applied research

Oriented basic research

Pure basic research
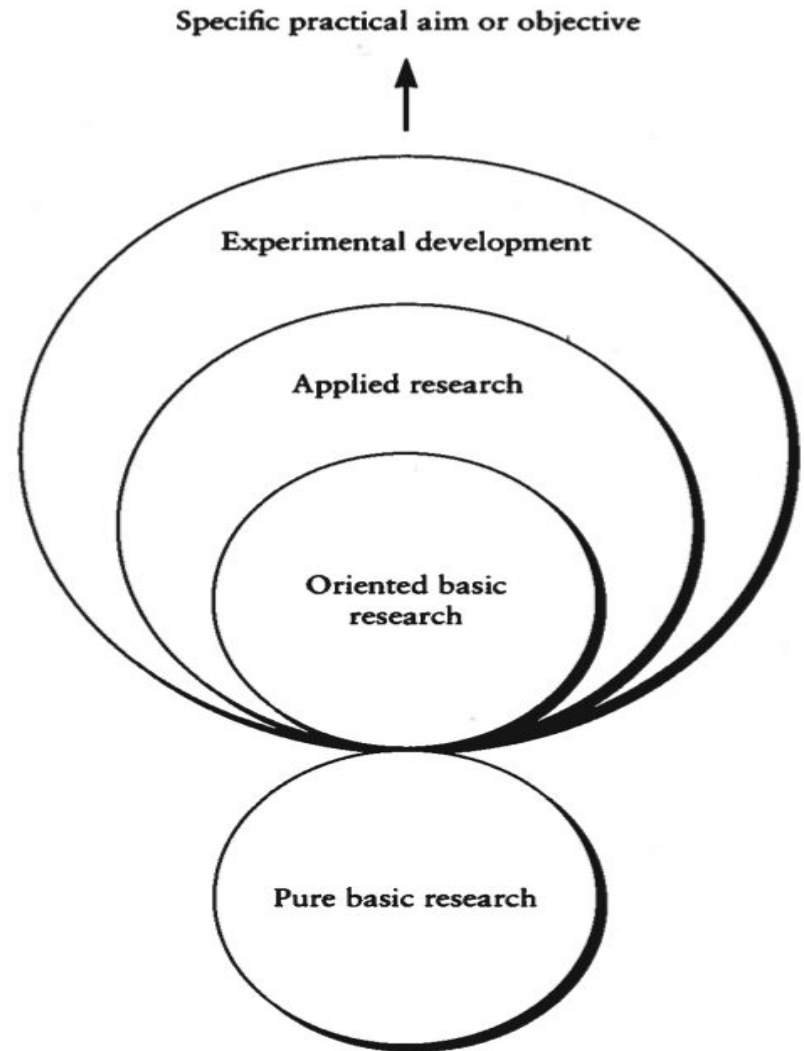
Modifying the paradigm

Modifying the paradigm
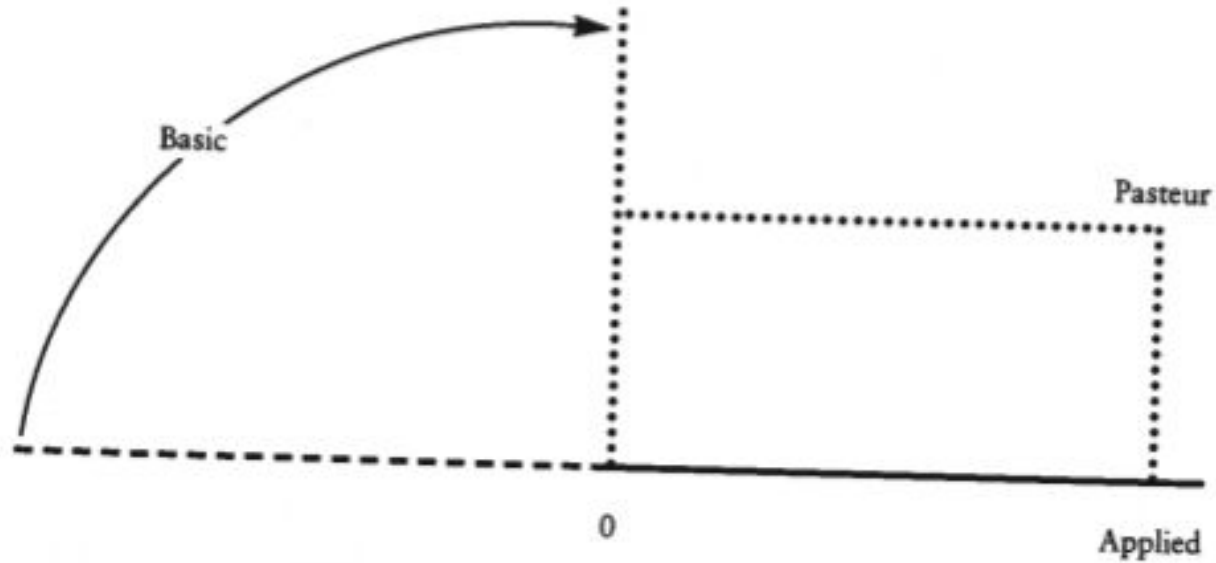
Modifying the paradigm

Research is inspired by:

	Considerations of use?	
	No	Yes
Quest for fundamental understanding? — Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
No		Pure applied research (Edison)

Why did Stokes divided this 2D plane into 4 quadrants instead of using the entire plane freely to represent all research?

- Stokes specifically forewarned the danger of misinterpretation and potential fixation on the (dichotomous) quadrant representation itself - *Hyeonsu*

- Representing all research freely using the entire plane can introduce ambiguity (as we see in some of the other models) - *Alireza*

- I would liken such a plane to the spectrum of a rainbow, where the left side (red) is research that is immediately applicable and the right side (purple) is research that is highly abstract - *Daniel*

- Much like the discussion about how basic and applied research are not on opposite ends of a 1D spectrum, the discussion of 4 quadrants is not diametrically opposed to using the entire plane freely - *Ariel*

- If an entire plane is used, it is difficult to accommodate other motivations other than the two - *Zhaowen*

State of Current research

Research is inspired by:

	Considerations of use?	
	No	Yes
Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
No		Pure applied research (Edison)

Quest for fundamental understanding?

Which quadrant does most HCI Research fall into?

Characterizing research ex ante or ex post
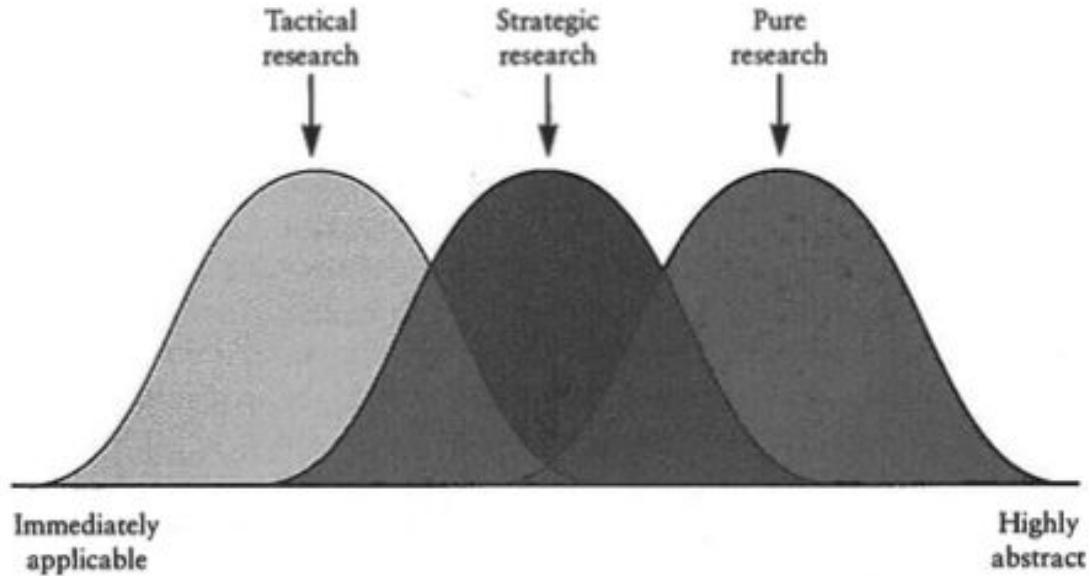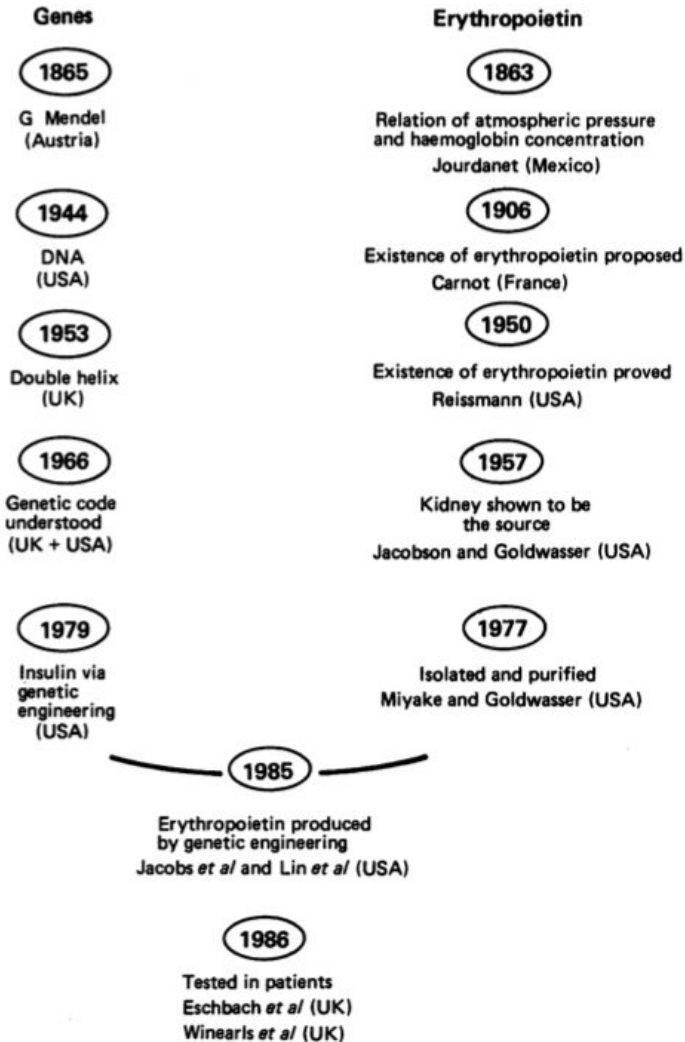
- ex ante -> based on forecasts rather than actual results,

- ex post -> based on actual results rather than forecast

How should we be thinking about research? In retrospect or in advance?

# Can the 2 dimensions be reduced to one?

Figure 3-6. *Australian Modification of Linear Model*

Tactical research

Strategic research

Pure research

Immediately applicable

Highly abstract

Comroe and Dripps Revisited

Genes

(1865)
G Mendel
(Austria)

(1944)
DNA
(USA)

(1953)
Double helix
(UK)

(1966)
Genetic code
understood
(UK + USA)

(1979)
Insulin via
genetic
engineering
(USA)

Erythropoietin

(1863)
Relation of atmospheric pressure
and haemoglobin concentration
Jourdanet (Mexico)

(1906)
Existence of erythropoietin proposed
Carnot (France)

(1950)
Existence of erythropoietin proved
Reissmann (USA)

(1957)
Kidney shown to be
the source
Jacobson and Goldwasser (USA)

(1977)
Isolated and purified
Miyake and Goldwasser (USA)

(1985)
Erythropoietin produced
by genetic engineering
Jacobs et al and Lin et al (USA)

(1986)
Tested in patients
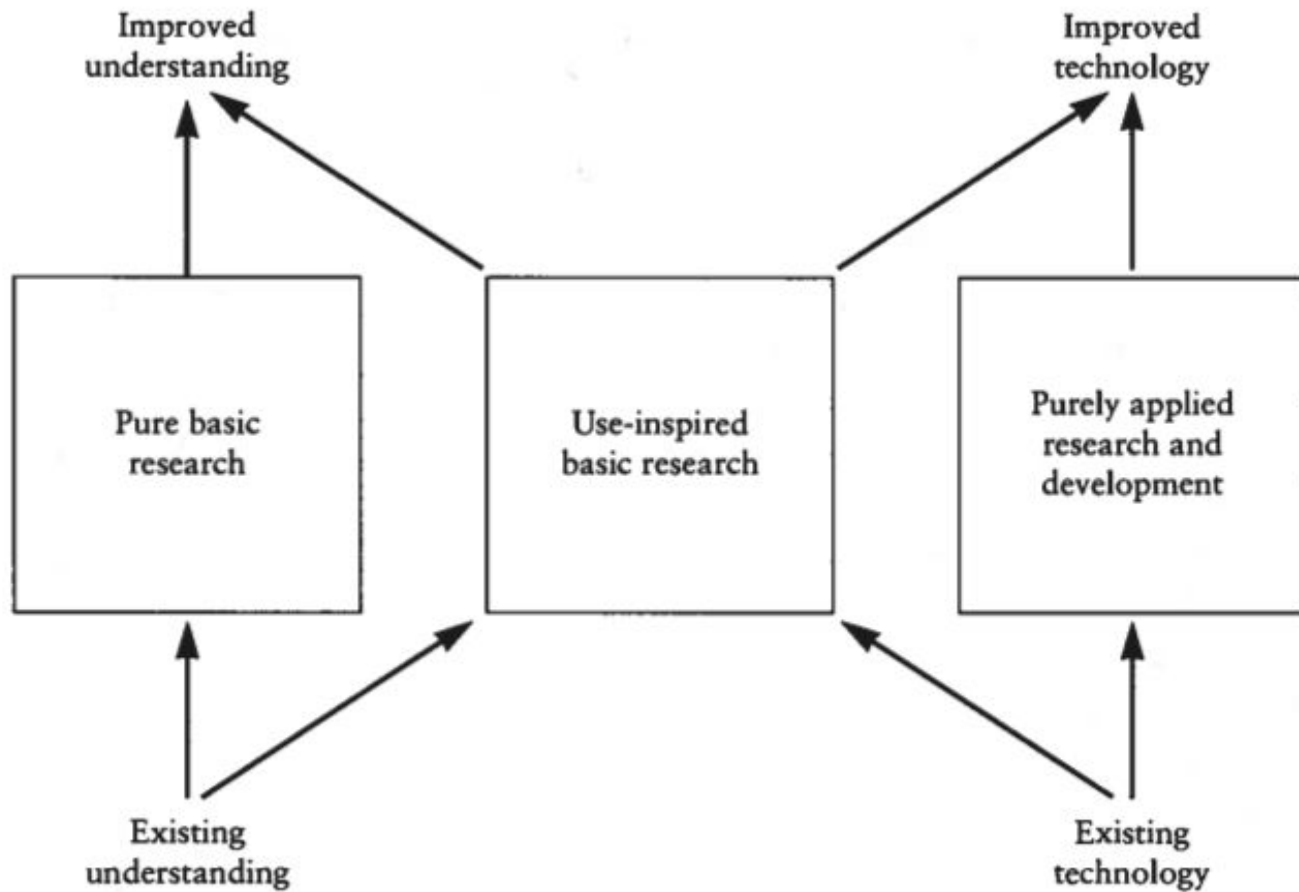Eschbach et al (UK)
Winearls et al (UK)

The development of erythropoietin: a recent example of innovation. The development of using erythropoietin in treating the anaemia of renal failure has been described by Professor Keith Peters, regius professor of physic in Cambridge, as equivalent to the development of using insulin for diabetes. The chart shows the importance of basic research. Another chart could probably be drawn with a shorter timescale and different emphases to show the importance of technical development. (Diagram kindly provided by Dr Chris Winnearls.)
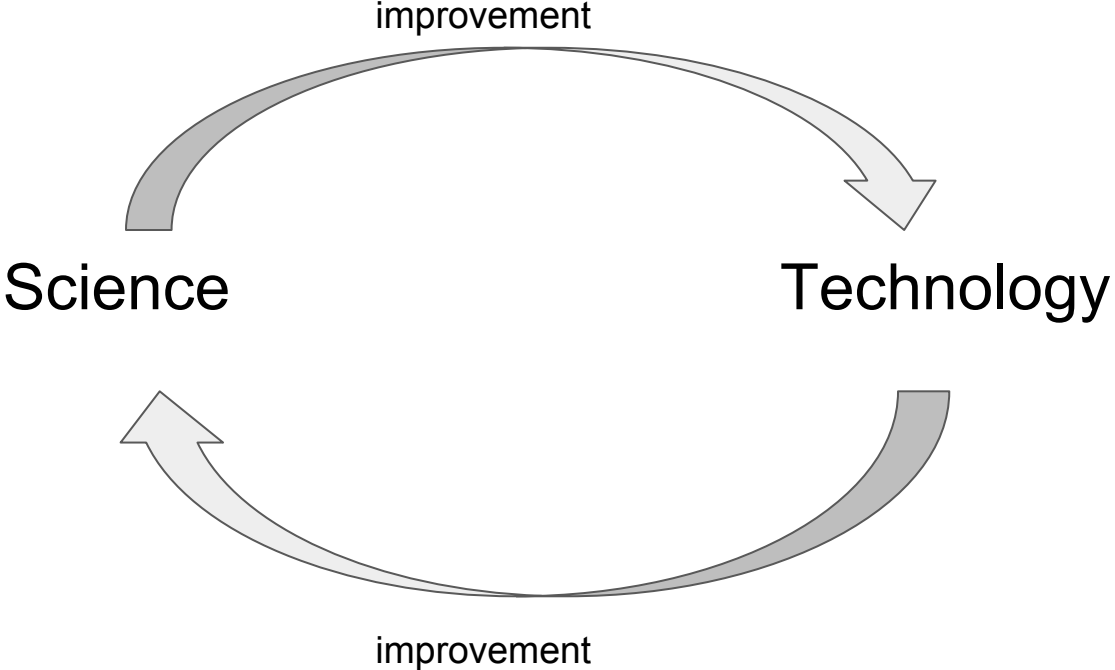
To replace the linear model of the postwar paradigm, we need a clearer understanding of the links between the dual but semiautonomous trajectories of basic scientific understanding and technological know-how.

Comments

- If we view science and technology as two different streamlines, then researches serve as boosts leading to improved theory, improved tech, or both, depending on the class of research - Enhao Cui

- This new emphasis on the interaction of, rather than the distance between, the two trajectories precisely captures the point of interest that has enormous potential consequences that reaches beyond the boundaries of scientific communities - HYEONSU

Improved understanding

Improved technology

Pure basic research

Use-inspired basic research

Purely applied research and development

Existing understanding

Existing technology

"The framework has come under heavy pressure as the policies to which it led seem less adequate for the needs of a different era"