DOCKING MODELS IN ORGANIZATION SCIENCE:
COMPARISON OF MARCH'S ORGANIZATIONAL CODE MODEL AND LEVINTHAL'S NK MODEL OF RUGGED LANDSCAPES

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- Steve Guerin
- James March
- Bill McKelvey
- Rick Riolo
- David Schwandt
- Steve Upton

Feynman on “Scientific Progress”

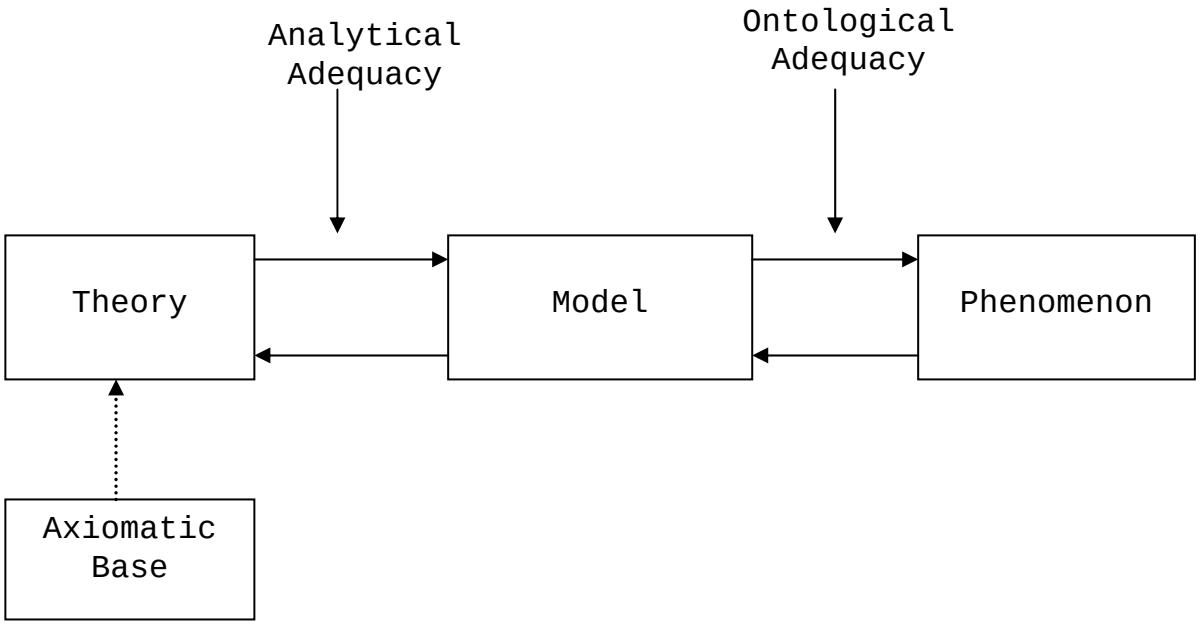
- While trying to pick a safe, Feynman is asked “are you getting anywhere?”
- Feynman’s reply:
  - “You can’t tell until you open it. But you have tried a lot of numbers that you know don’t work!”

Feynman, R. P. (1996) *Feynman Lectures on Computing* (p. 292-293).

Research Overview

- Brief review of computational models in Organization Science
- Model Docking
- Replication, Replication, Replication…
- Some encouraging results but *Progress* ?
  - Two outer safes “open”
  - Inner safe not yet open, but I have heard some “clicks”
- Discussion

Model-Centered Organization Science (1 of 2)



- **"Semantic Conception" of Philosophy of Science: research bifurcated into two domains.**
- **Each domain is predicated on experimentation with models.**
  - ***Analytical*** **: consistency between conceptual predictions and model behavior**
  - ***Ontological*** **: consistency between model behavior and the phenomenon under investigation.**

-Adapted from McKelvey (1999, p. 17; 2002)

Computational Models in Organization Science

- James March and colleagues, stemming from March and Simon (1958)
  - Behavioral Theory of Firm (1963)
  - Garbage Can Theory of Organizational Choice (1972)
  - Adaptive Organizational Search (1981)
  - Exploration and Exploitation (1991)
- Daniel Levinthal and colleagues, stemming from Stuart Kauffman's (1993) NK model
  - Adaptation on Rugged Landscapes (1997)
  - More than two dozen extensions of this model
- Kathleen Carley and colleagues, org. design and task structure; stemming from Carley (1992)
- And others...

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Why March's (1991) OCM?

- March's (1991) paper is *culmination of three decades* of modeling; widely accepted for its depiction of the adaptive tension between Exploration and Exploitation.
- OCM formally depicts the rules for Member socialization *toward* the Organization while the Organization learns *from* its Members.
- *Multi-level nature of complex system*; study depicts inter-dependence of Environmental turbulence and the corresponding adaptation at the levels of the Organization and its microstates.

Why Levinthal's (1997) NK Model?

- Intended to respond to ongoing debate regarding organizational adaptation and selection (i.e., evolutionary economics vs organizational ecology)
- Difficult to operationalize with empirical research
- Has ***not*** been critically analyzed by the Organization Science community*
  - For analytical adequacy
  - For ontological adequacy
- However, has been repeatedly extended and applied

*Sole exceptions are McKelvey's (1997; 1999) analysis of Kauffman's NK model

“Docking” of Models*

- Analogous to orbital docking of dissimilar spacecraft.
- Provides a basis for critical experiments and for tests of whether one model can subsume another.
- Specific research questions to address:
  - “What does it mean for two models to be equivalent?”
  - “How can different standards of equivalence be statistically evaluated?”
  - “How do subtle differences in model design affect the results?”
- Technical Approach
  - Analytical methodology roughly analogous to that used when a second investigator in a laboratory science attempts to reproduce results obtained in a first investigator’s laboratory.

* Axtell, Axelrod, Epstein and Cohen. (1996). Aligning Simulation Models: A Case Study and Results. *Computational and Mathematical Organization Theory* 1 (2): 123-141.

3 Types of Equivalence*

Model Review
Docking
Replication
Demonstrations
Some Results
Discussion

- Declaration of a success criterion
- **Numerical** - the two models produce quantitative measures that are *identical*
- **Distributional** - the two models produce distributions of results that are *statistically indistinguishable*
- **Relational** – the two models produce the same internal, *qualitative* relationships among their results

* Axtell, et al. (1996). Aligning Simulation Models. *Computational and Mathematical Organization Theory* 1 (2): 123-141.

Why Replication?

- Model-centered Organization Science is predicated on experimentation with formal models (McKelvey, 2002).
- Successful model replication provides a credible baseline from which to extend the original research.
  - "cumulative disciplinary theorizing" (Axtell, Axelrod, Epstein & Cohen, 1996, p. 22)
  - March's OCM captures *intra*-Organizational dynamics and should therefore comprise the core of a model to investigate Organization-Environment and *inter*-Organizational dynamics.

Model Replications

- March's Organizational Code Model
- Levinthal's NK model

Replication of March's Org Code Model*

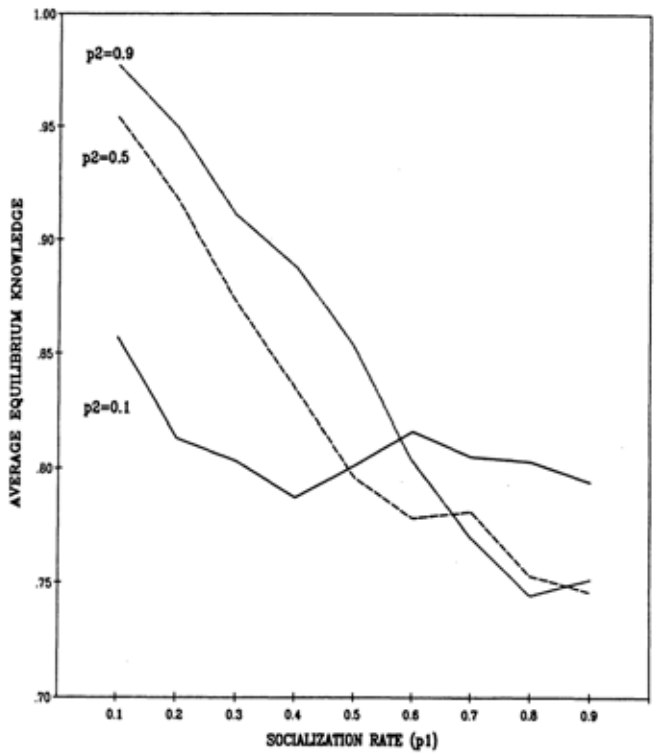
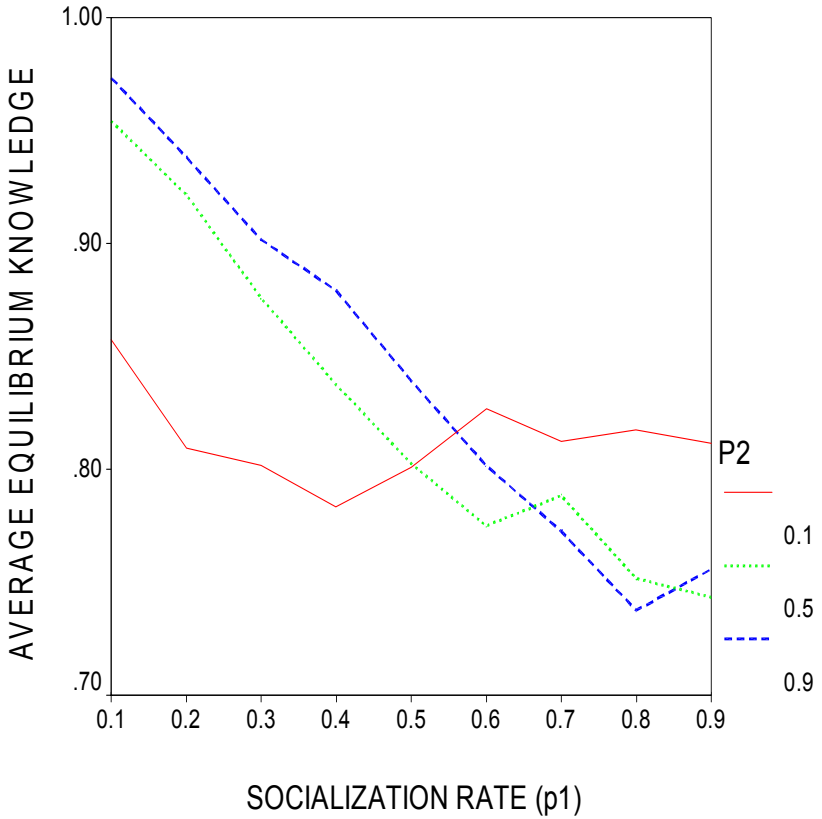


FIGURE 1. Effect of Learning Rates (p_1, p_2) on Equilibrium Knowledge. $M = 30$; $N = 50$; 80 Iterations. (March, 1991, p. 76)



*Tivnan, B. F. (Forthcoming). *March-ing Forward to New Explorations: Re-Formulation and Replication of March's Organizational Code Model.* Paper presented at the 2007 Academy of Management Annual Meeting, Philadelphia, PA.

Levinthal's NK Model

- Formulation of Kauffman's NK Model
- Formulation of Levinthal's Application of the NK model to Organization Science 
- Replication Results
- Demonstration of Levinthal's NK

Fitness Landscapes

- Attributed to Wright (1932).
- Biological metaphor to model the synthesis of evolution, taxonomy and genetics.
- Three major components
  - Configuration space
  - Fitness functions
  - Move rules to define the *adaptive walk*

NK Formulation* (1 of 4)

- N - number of significant components or attributes comprising an adaptive entity
- A - number of discrete levels each *n* can assume, typically binary
- K - number of epistatic links (i.e., number of other agents that are interdependent with a given agent)

* Kauffman (1993)

NK Formulation* (2 of 4)

- A^N - number of vertices in the Configuration Space
- D - number of dimensions (i.e., number of nearest neighbors for each); D = (A-1) N

* Kauffman (1993)

NK Formulation (3 of 4)

- Configuration Space as a Hypercube
- For our purposes A=2, therefore this graphic depicts the configuration space for N = 4.
- 2^4 = 16, number of vertices in the Configuration Space

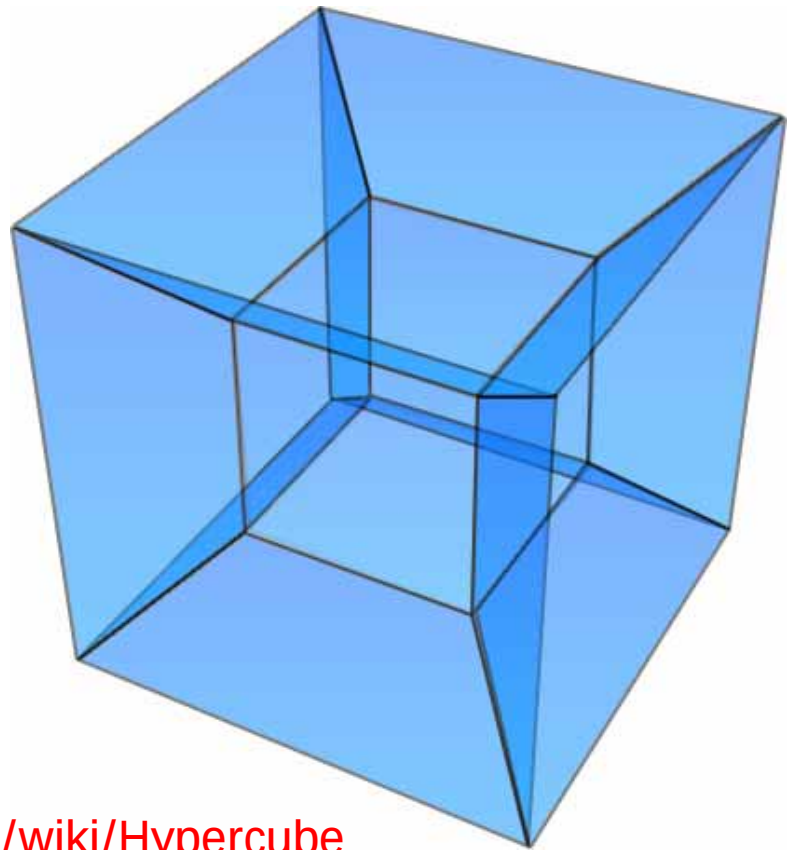


*Image from http://en.wikipedia.org/wiki/Hypercube

NK Formulation* (4 of 4)

Model Review
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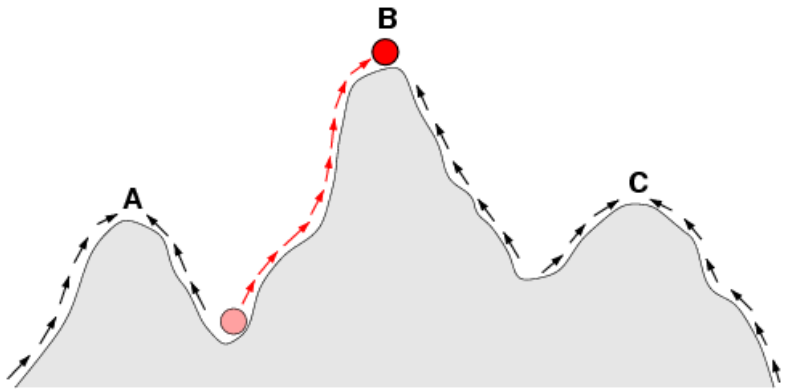
- Interdependence Parameter, K
  - "Tunes" the fitness landscape
  - Range: 0 to N-1
  - When K = 0,
    - Landscape is highly correlated between fitness of nearest neighbors
    - One local optimum, therefore global
  - As K $\longrightarrow$ N-1,
    - Landscape is highly rugged; little to no correlation between fitness of nearest neighbors
    - Many local optima with steep gradients
  - *Complexity Catastrophe:* As K increases, the number of peaks in the fitness landscapes vastly increases. But the difference between peaks and valleys diminishes, so much so, that selection pressure cannot account for emergent order.

* Kauffman (1993)

Fitness Landscape

- Agents will always hill-climb to higher fitness peaks
  - Not necessarily by steepest gradient.
  - Therefore, apt to get stuck on local optima when using nearest-neighbor adaptive walk.



Cartoon only, actual landscape is NOT continuous.*

*Image from http://en.wikipedia.org/wiki/Fitness_landscape

Calculating Fitness

- For each of the N attributes:
  - Determine its K epistatic links
  - Refer to Look-Up Table for the fitness contribution of that attribute
- Overall fitness for the string equals the average fitness of the N attributes

Look-up Table Example

- Look-up Table for k = 2

n	k_1	k_2	Uniform [0,1]
0.0	0.0	0.0	0.2361579623539007
0.0	0.0	1.0	0.04482660815119743 3
0.0	1.0	0.0	0.323631684295833 1
0.0	1.0	1.0	0.4343449196312576 5
1.0	0.0	0.0	0.778498607920482 8
1.0	0.0	1.0	0.2003078369889408 3
1.0	1.0	0.0	0.229520164662972 1
1.0	1.0	1.0	0.94726461614482 1

Fitness Example (N=3, K=1)

- Look-up Table for k = 1

n	k_1	Uniform [0,1]
0.0	0.0	0.3117464208044112
0.0	1.0	0.9806047666352242
1.0	0.0	0.9341068086214364
1.0	1.0	0.8791293741669506

Fitness Example (Continued)

String: 000 Fitness: 0.311...

String: 111 Fitness: 0.879...

But, String: 101

Fitness: (0.934 + 0.980 + 0.879) / 3
= 0.931

Levinthal's NK Formulation (1 of 3)

- Attribute string has N elements
  - Example: 0111 for N=4
- Determination of K epistatic links
  - Attribute string configured as a torus
  - Epistatic links to the k successive attributes in the string
- Population of 100 organizations searching on the same fitness landscape
- Organizational Form ≡ An unique Attribute String

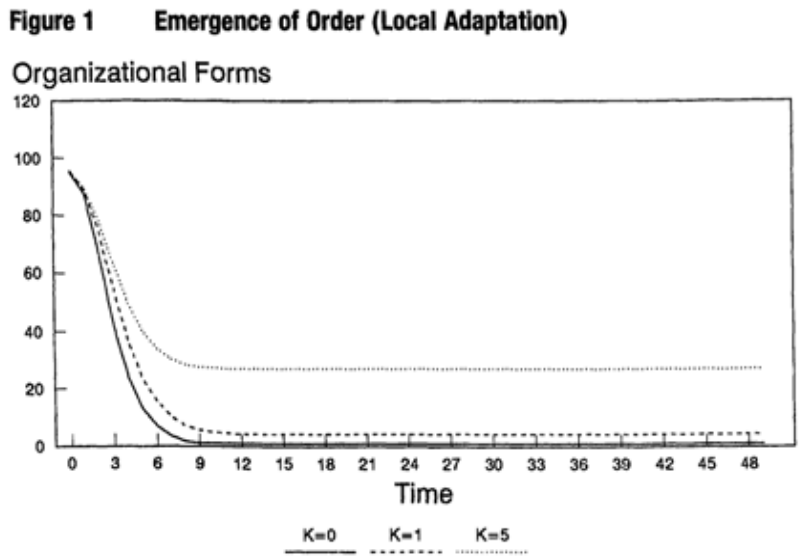
Levinthal's NK Formulation (2 of 3)

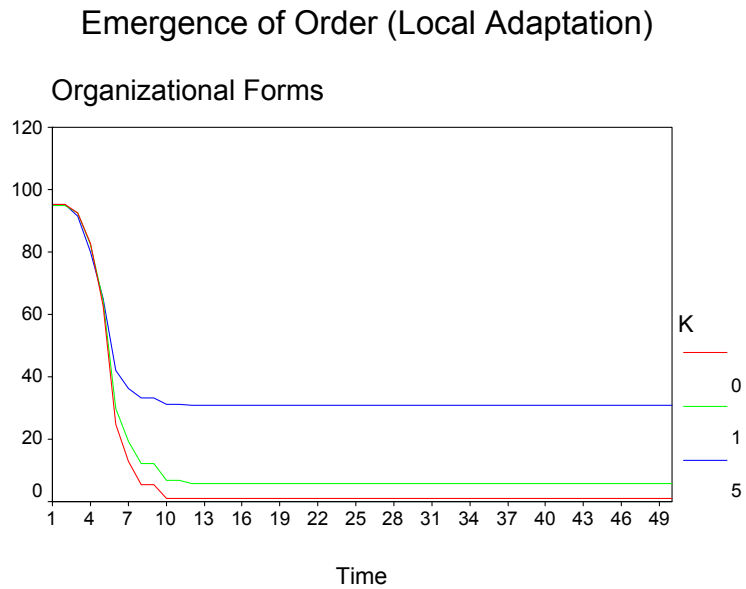
- Search ≡ Organizations search other locations in the Configuration Space; if higher fitness, move there
- Local Search – nearest-neighbor, adaptive search
  - 0011 → 0001 or 1011
  - 0011 ✗→ 1111
- Distant Search – randomly determine all N attributes in the Attribute String
  - 0011 → 1100
  - 0011 → 0100

Levinthal's NK Formulation (3 of 3)

- Emergence of Order – each organization in the population begins at a randomly determined location in the Configuration Space; adaptation dissipates heterogeneity of organization forms
- Radiation of Organizational Forms – all organizations in the population begin at the SAME randomly determined location in the Configuration Space

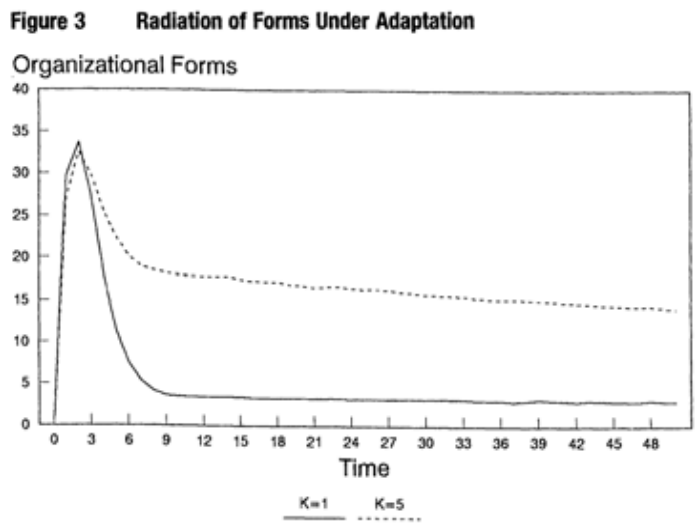
Replication of Levinthal's (1997) Baseline Model

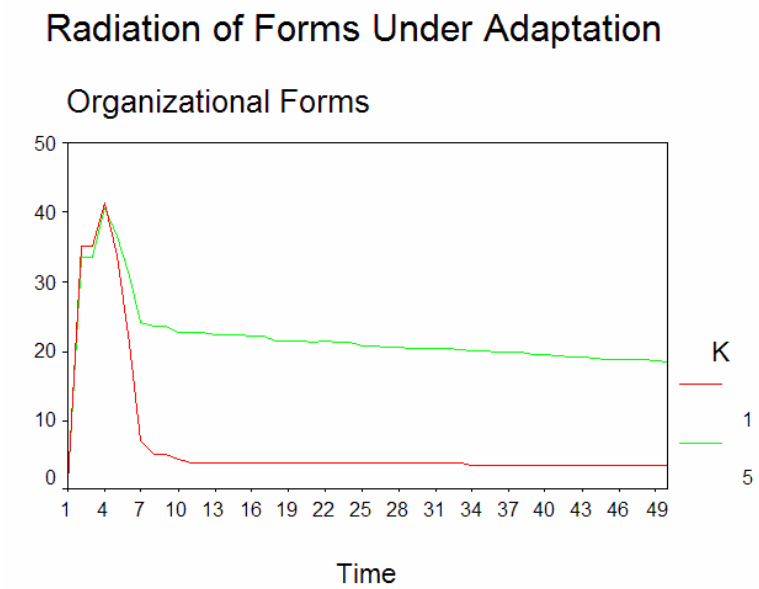




(Levinthal, 1997, p. 940)

Replication of Levinthal's (1997) Model - Radiation





(Levinthal, 1997, p. 942)

Demonstrations

- Repast models
  - March's Organizational Code Model
  - Levinthal's NK Model
- Happy to run the demonstrations offline

Some Results

- Replication of March's OCM: distributional equivalence
- Replication of Levinthal's NK model: relational equivalence
- Docking progress to date
  - For extreme case of K = 0
- Much more work to do...

Takeaways

- Replication provides unsurpassed insights into model dynamics.
- Docking contributes to a cumulative science.

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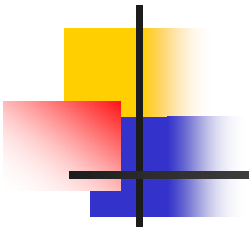
Accomplices



Questions???

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