Complex Systems Models of Urban and Regional Systems

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Plan of Talk

- Models for Decision Support - Integrated?

- Complex Systems and Knowledge

- Dynamic Spatial Self-Organising Models - Success and Failure

- Conclusions

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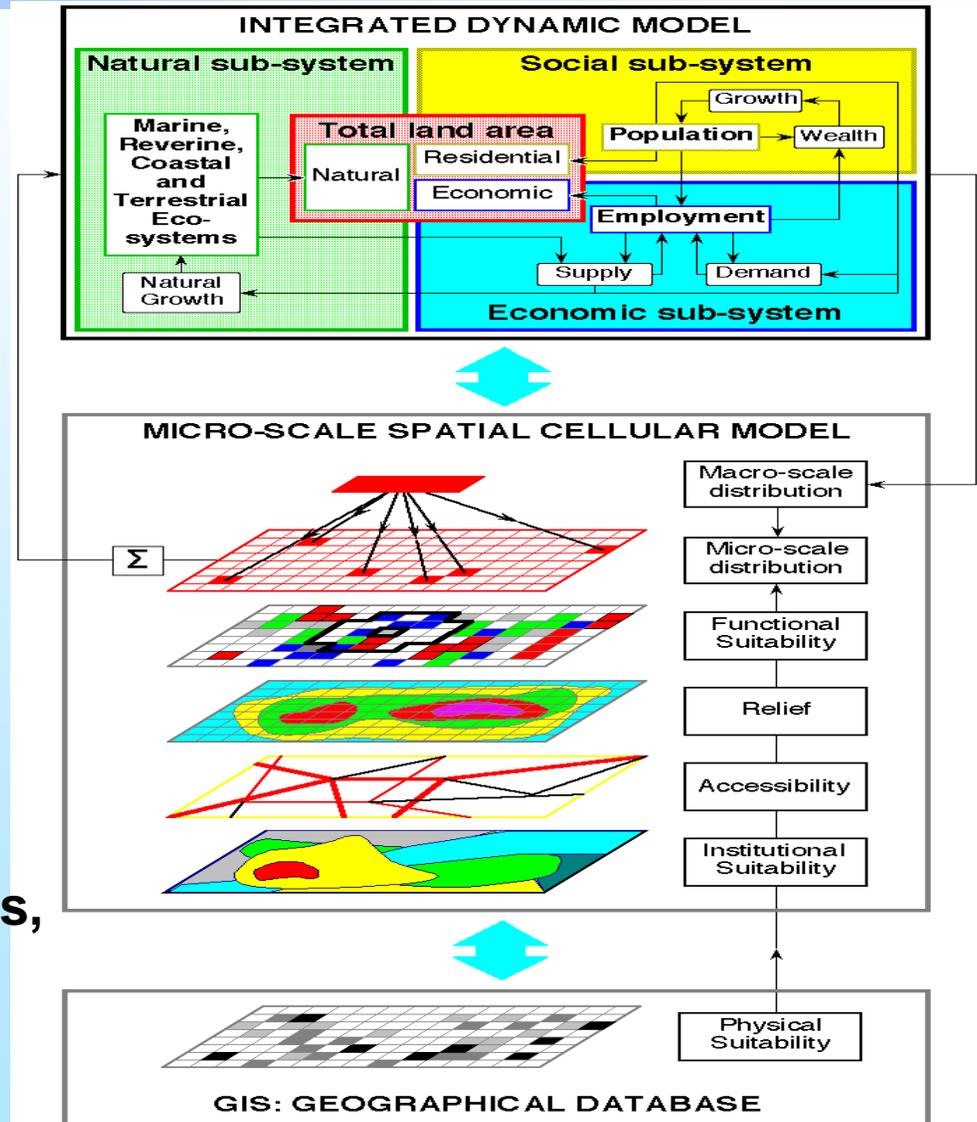# Try to model the "system" - and then do something to it!!!!
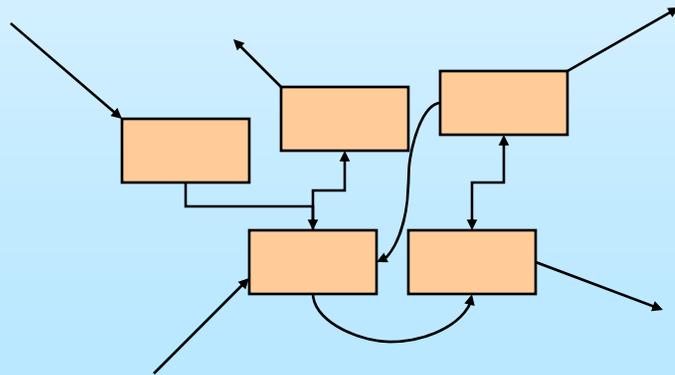
- What is it made of?

- What is going on that changes the things it is made of?

- Can I define a System - and model its behaviour?

- What would it do if???????

The Urban and Regional System….
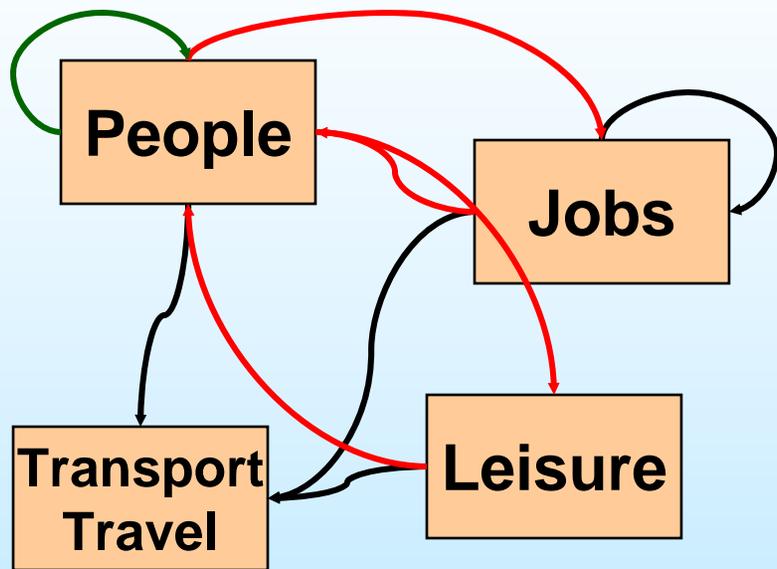
Changing transport costs or access changes locational choices of people and activities, that change the locational choicesof people and **activities,** that change the locational choice of people and activities…..
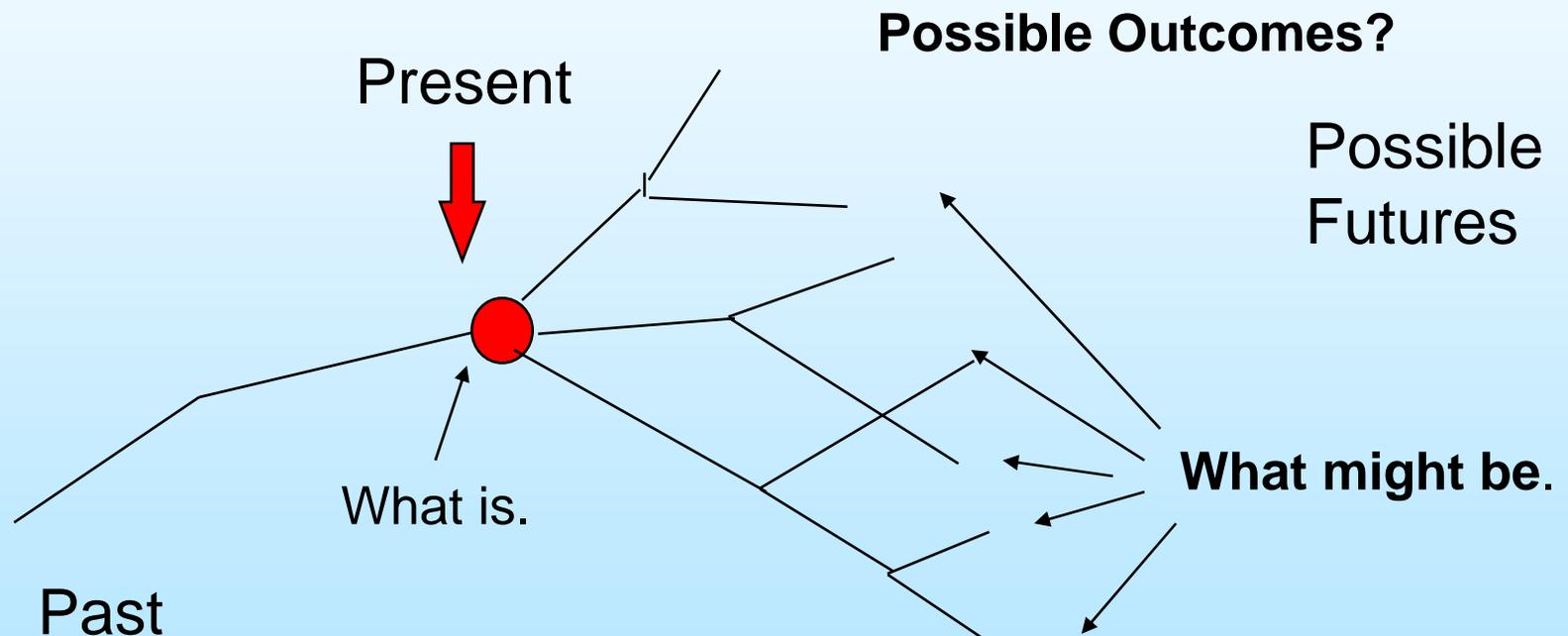
INTEGRATED DYNAMIC MODEL

Natural sub-system

Social sub-system

Marine, Reverine, Coastal and Terrestrial Eco-systems

Total land area

Natural

Residential

Economic

Natural Growth

Growth

Population

Wealth

Employment

Supply

Demand

Economic sub-system

MICRO-SCALE SPATIAL CELLULAR MODEL

Macro-scale distribution

Micro-scale distribution

Functional Suitability

Relief

Accessibility

Institutional Suitability

Physical Suitability

GIS: GEOGRAPHICAL DATABASE

People

Jobs

Transport Travel

Leisure

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The Underlying Structure is…..

Socio-economic groups
Age pyramid
Family types
Demography
In/out Migration

Types of Activity
Inputs/Outputs
Type of Employees
Spatial Needs
Communications
Salaries, wages

People

Jobs

Transport
Travel

Leisure

Walking
Cycling
Driving
Buses
Trains
Planes
Trams...

One Indicator of the spatial dynamics that affects the spatial dynamics…….

Land Uses

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Policy: we need to understand the changes

- For a model to be useful in influencing the future favourably, it must include the effects of the connected factors - otherwise the "predictions" will be WRONG!

- So, locational decisions (employment, residential…) must be coupled to any model aimed at making transportation decisions

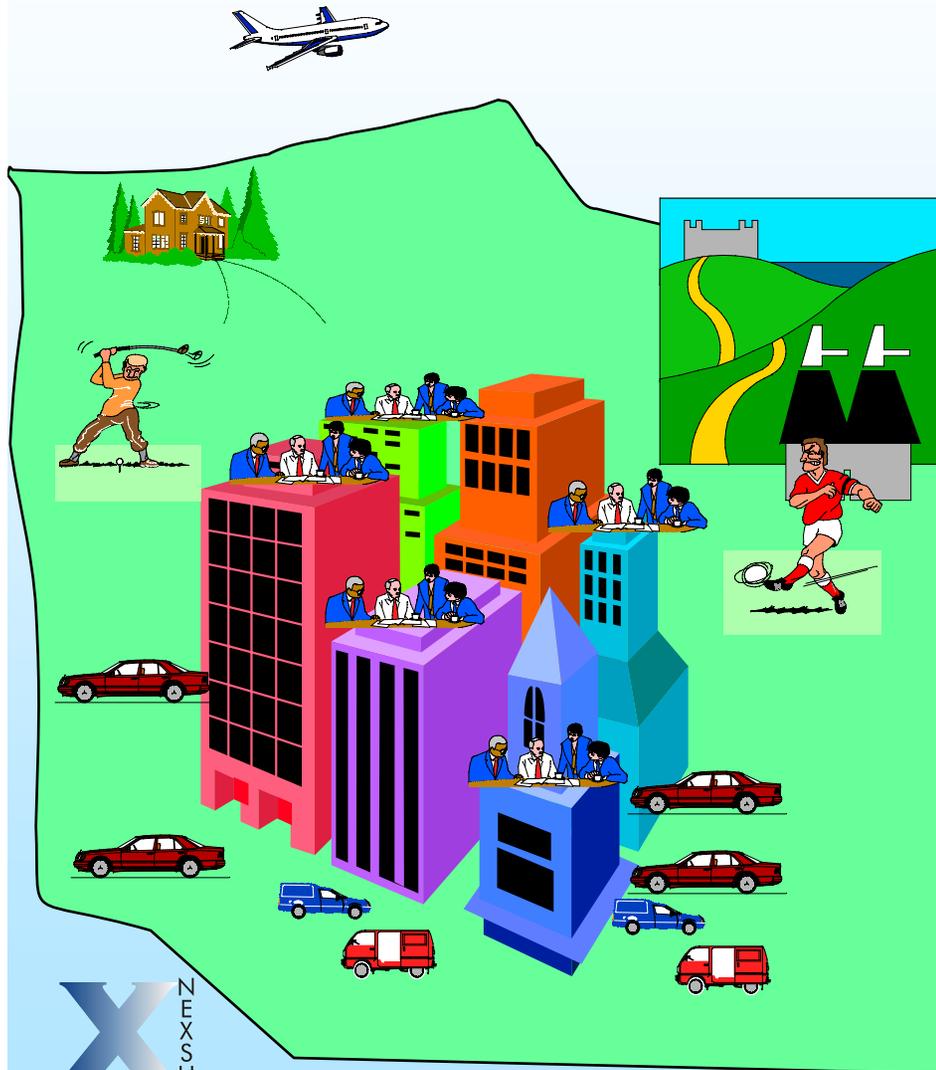- But these decisions are INTERDEPENDENT and form a **co-evolutionary complex…...**

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Policy and Planning assume choices....

If the future is unknowable then so is the past!

Present

Possible Outcomes?

Possible Futures

What is.

What might be.

Past

Can we understand how systems CHANGI

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How do we gain knowledge about a system?

- In order to gain knowledge about a situation we may use experience - trial and error

- But we also want to use REASON. This is fine for planets, but can we use REASON when humans are involved?

- We must simplify reality and look for underlying stable patterns

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Building Mathematical Models

The Basis of Modelling….

The Newtonian View….

• The Falling Apple told Newton that predictable forces governed motion

• The Planetary Motion and all the stars and galaxies are explained by just the same formula!!!
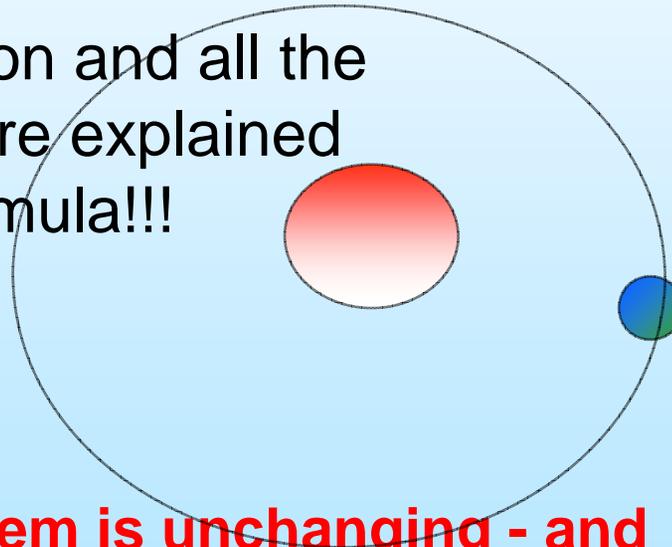
**A Newtonian system is unchanging - and hence can give wonderfully precise "predictions"**

Beginning

Newton

Later...

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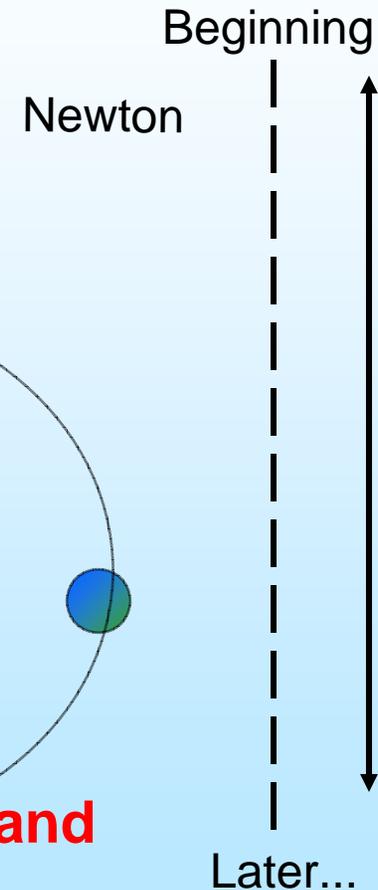
Analysis to mechanisms gave PREDICTION

- Newton saw that the apple falling was universal
- The planets, moons, stars and galaxies all obeyed his law. Prediction in the heavens was possible.

- But the heavens are not the earth!! On earth friction and viscosity meant that real systems "ran down".
- Systems that were isolated went to equilibrium….
- Prediction on earth was possible.

  - **Either steady motion, or death!**

Around the early 70s - surprises….

- Lorentz had already noticed CHAOS in atmospheric simulations…..

- Prigogine & co in Brussels and Austin, explored the behaviour of "open systems". Dissipative Structures. Prediction was elusive.

- Haken & co in Bielefeld and Stuttgart, exploring behaviour of the laser found interesting SYNERGETIC behaviours….

- Open systems with non-linear interactions could spontaneously self-organise. Dynamic spatial structures were the result of the interactions between the underlying entities…..

The Belousov-Zhabotinsky Reaction

The Brusselator!!!

A –> X
B + X –> Y + D
2X + Y –> 3X
X –> F
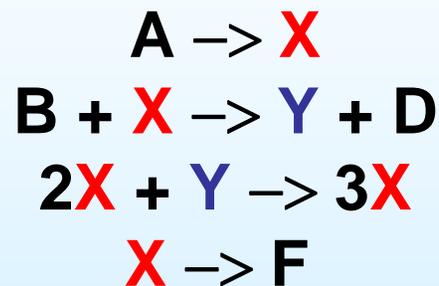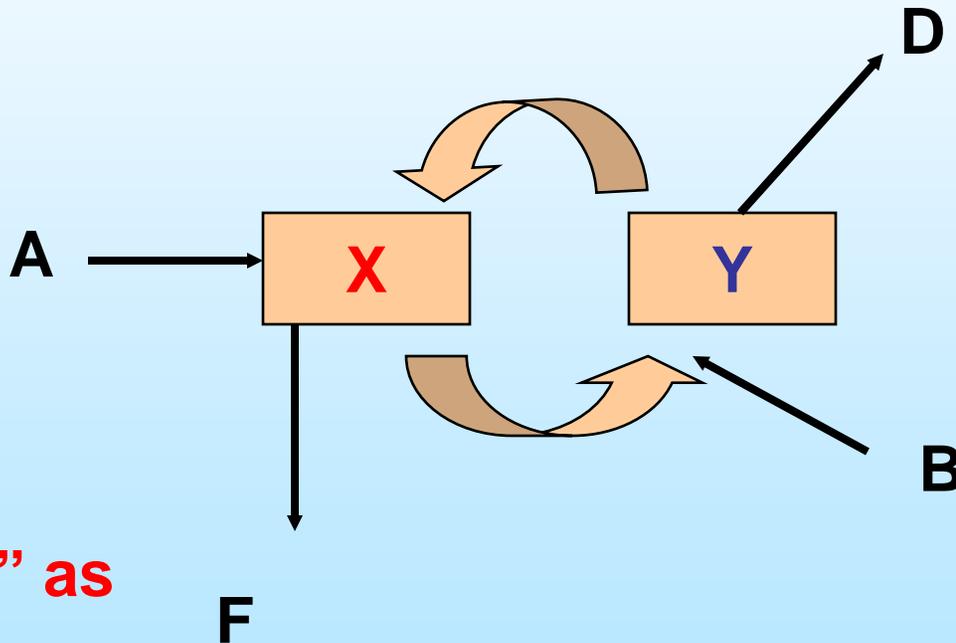
A simple non-linear chemical reaction. Imagine a "business" as simple as this!

The Belousov-Zhabotinsky Reaction

A test tube with self-organising reactions…….

Zab5.exe
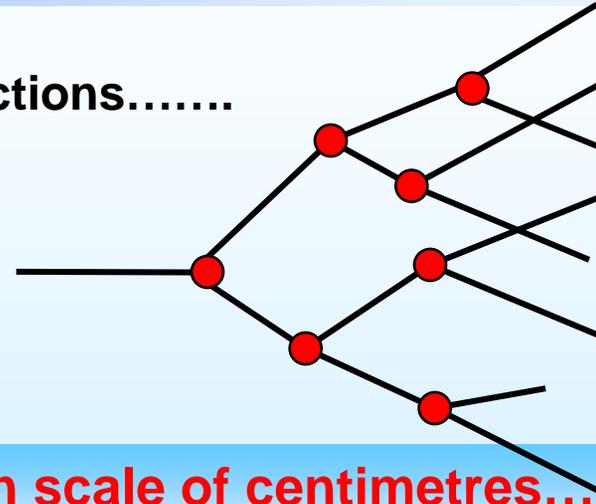
**Molecules 10^{-8} create structure on scale of centimetres…….
No planner, no organiser, no architect….**

**Different patterns for the same conditions! Complex
dynamic patterns that self-organise! Many possible
patterns of dynamic behaviour. Stationary, cyclic or
chaotic patterns, impossible to predict, triggered by
small fluctuations. Non-average is what matters.
Emergent behaviour, symmetry breaking, innovation**

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(Even) A Non-Linear Chemical Reaction is creative, unpredictable…...

The trillions of molecules can self-organise into patterns that allow the system to "fit" its environment…

Adaptive self-organisation

What possible futures?

- Is the response to an action to go from one equilibrium to another?

- Or is it that the changes that a system is undergoing may be affected by some action?

- If the latter, then we need to understand the "spatial dynamics" of a system and see how it might be changed.

Action

Later...

Action

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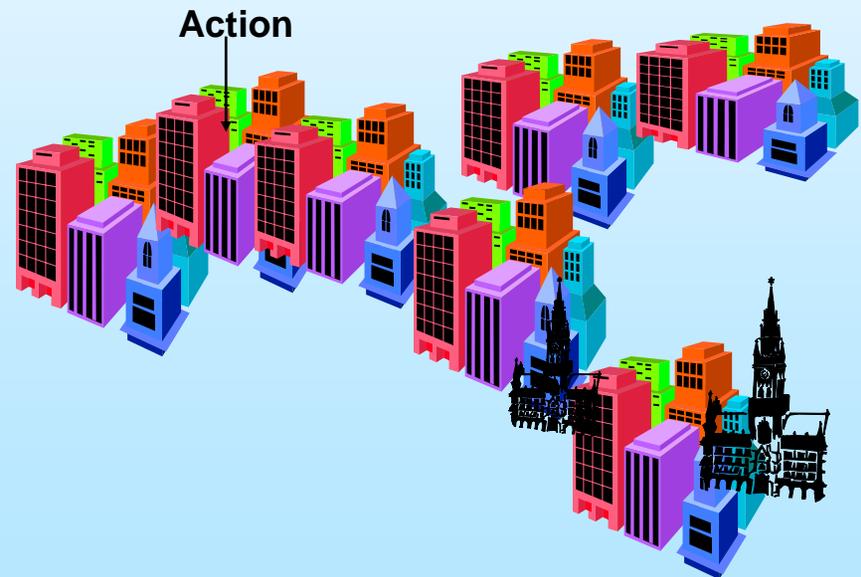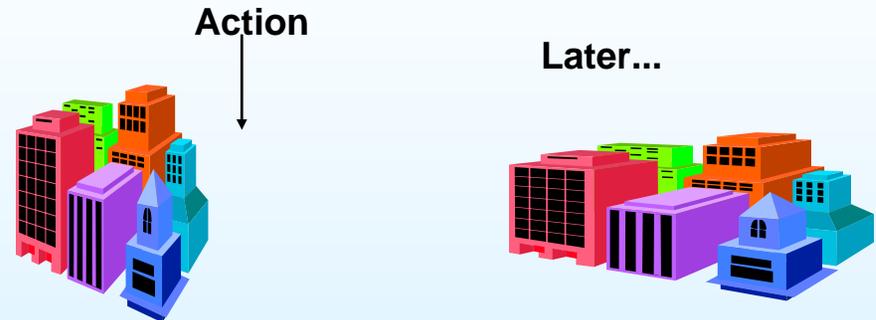
Understanding arises from ASSUMPTIONS -

1 that I can put a **BOUNDARY** around my system, and explain something from what is inside

2 that I know the key causal mechanisms, and can **CLASSIFY** the parts and choose the variables

3 that within each variable X, individuals are average - **STEREOTYPES**. (No microdiversity)

4 that events occur at their average rate, defining the "smooth" **MECHANISMS** of dynamic equations. (No luck or local circumstance)

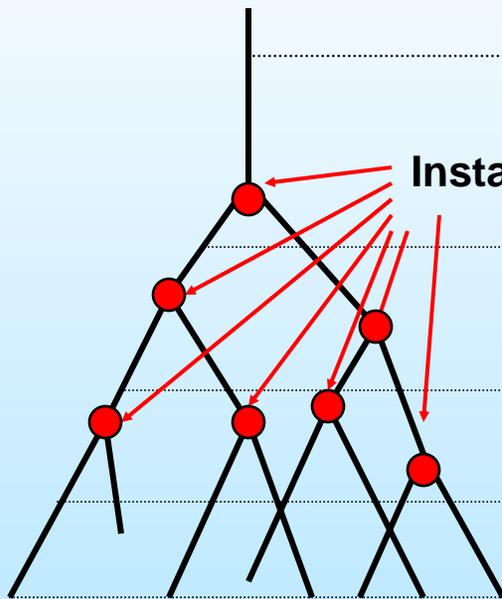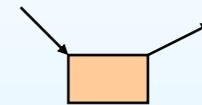**But we often forget to mention them**

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Complexity - Simplicity: Assumptions
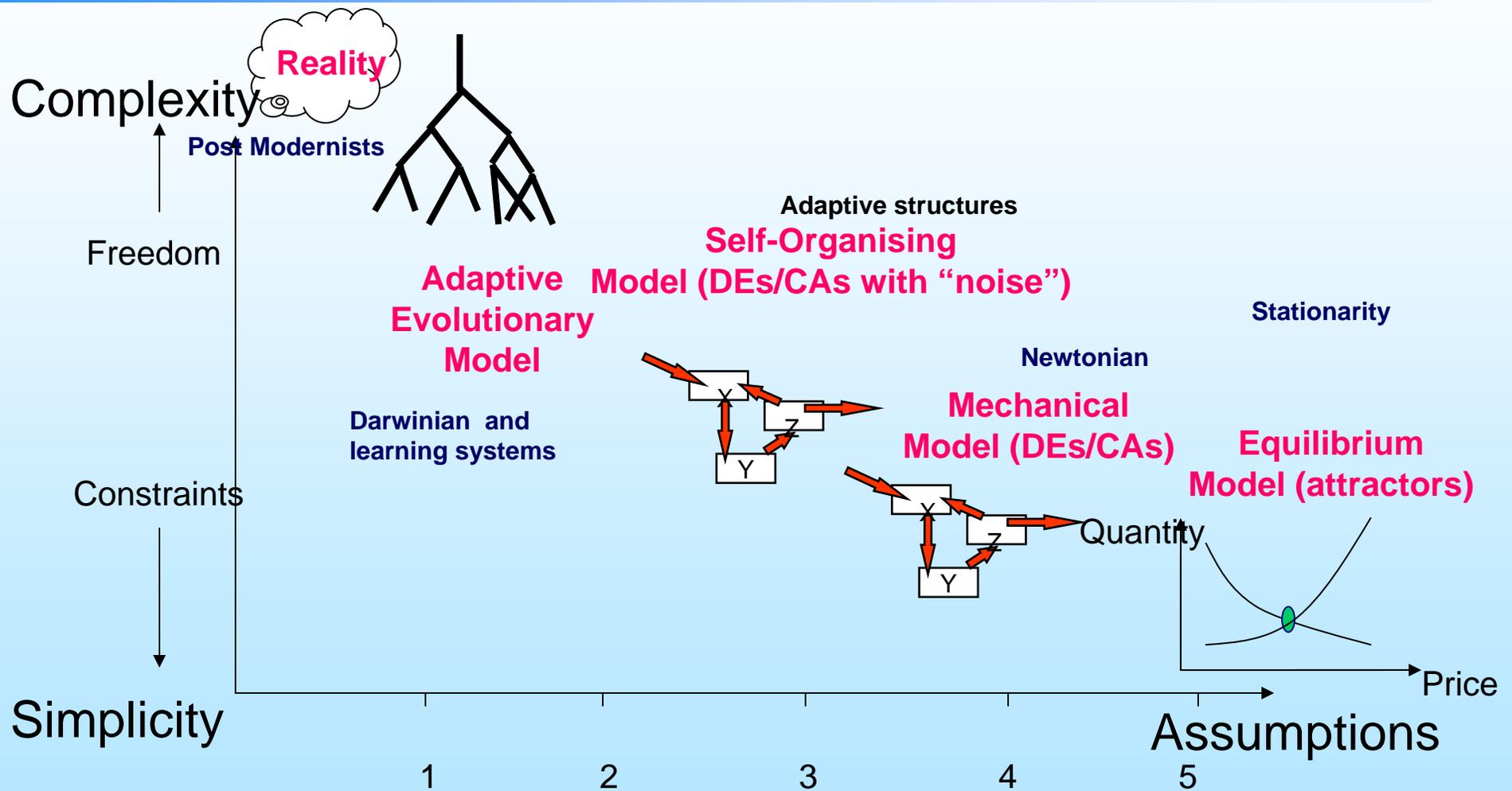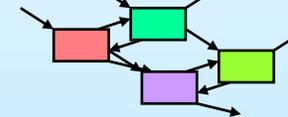
The Darwinian View….
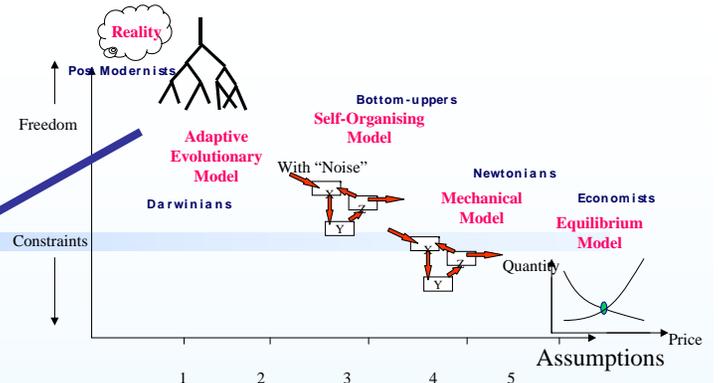
Beginning

Instabilities

System 1
1 type
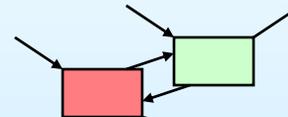
System 2
2 types

System 3
4 types

System 4
8 types

System 5
6 types
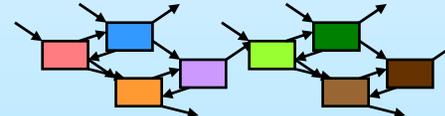
Later...

Structural Change occurs...
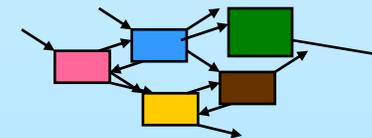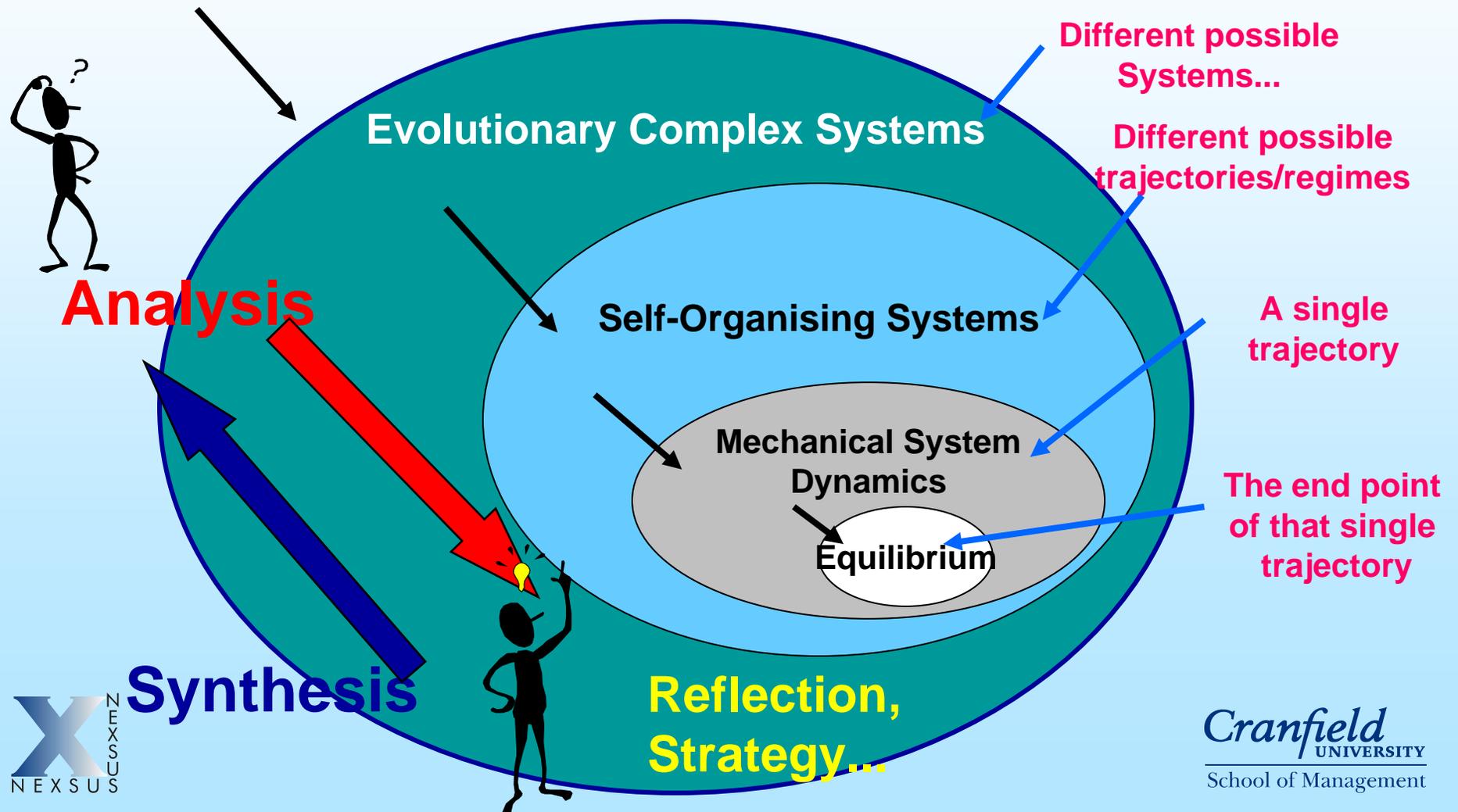
Time

New Types, and
New Attributes

Hill-climbs separated by instabilities..

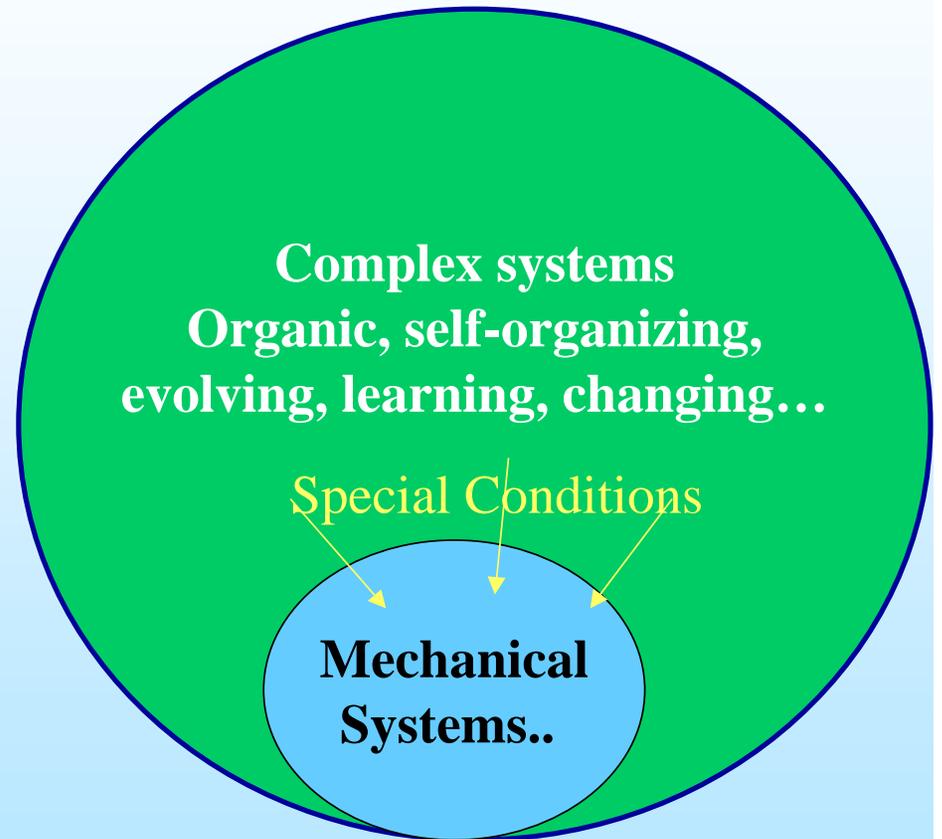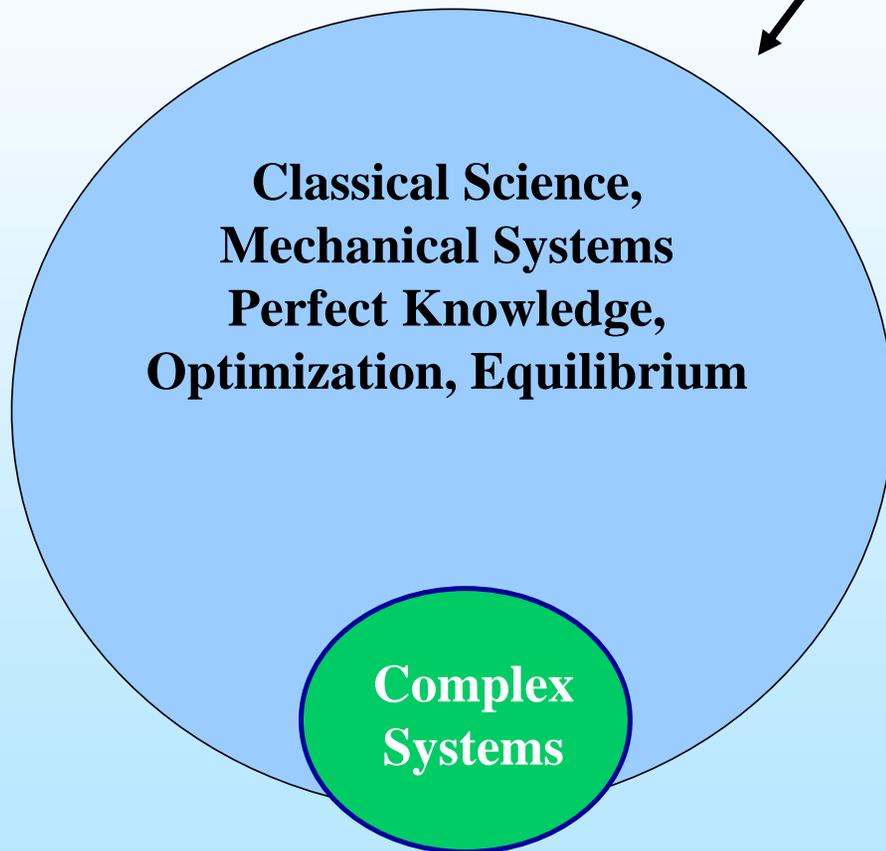# "Darwin" generates successive "Newtons"

- Real, qualitative, structural change occurs over time! The network of interacting entities evolves.

- Successive "Newtonian" systems emerge, but they are "separated" by instabilities

- Can we predict anything "beyond" an instability?

- Or should we try to be "evolutionary" and deal with whatever lies beyond?

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Simplicity is contained within Complexity

Subjective, narrative "reality"…..

No formal relations…….

Different possible Systems...

Evolutionary Complex Systems

Different possible trajectories/regimes

Analysis

Self-Organising Systems

A single trajectory

Mechanical System Dynamics

The end point of that single trajectory

Equilibrium

Synthesis

Reflection, Strategy...

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Rationality is not enough!!!!!

PAST
Knowledge
Understanding..

TIME

Complexity

Design,
Decisions,
Strategy,
Investments...

FUTURE…..
Incomplete Information
Imperfect Knowledge,
Surprise..

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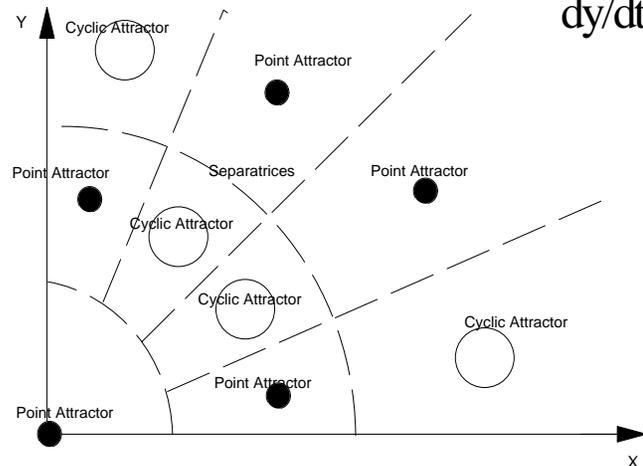School of Management
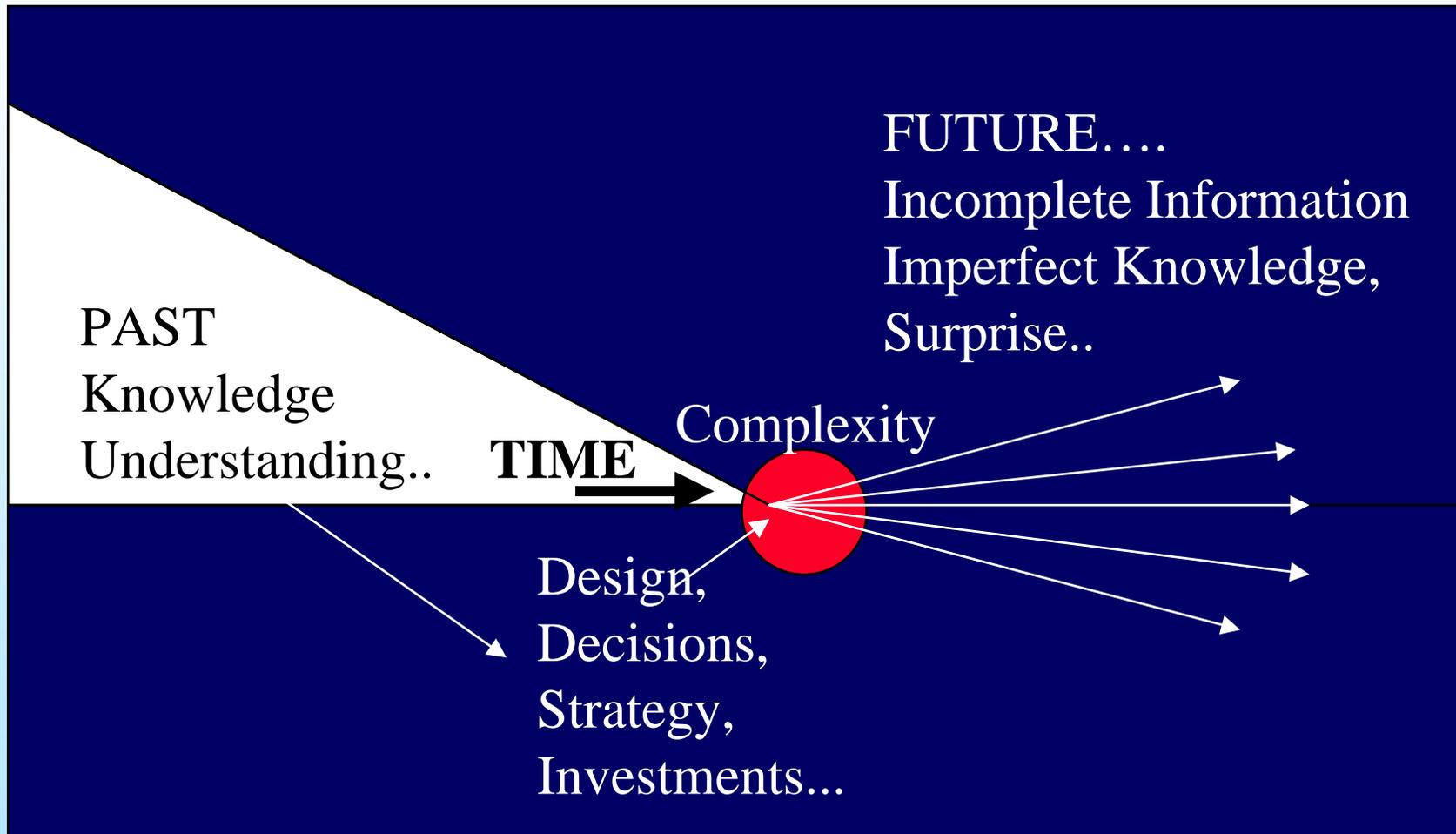
What is a Complex System?

- **A System that can, of itself, have more than one future**
  - some non-linear physical and chemical systems (Brusselator, Convector…)
  - living organisms
  - families, groups, organisations, firms, communities, disciplines……
  - towns, cities, economic sectors, markets, Supply Chains, business networks…….

They are all around us - and we are one ourselves!

Self-Organising Non-Linear Systems -
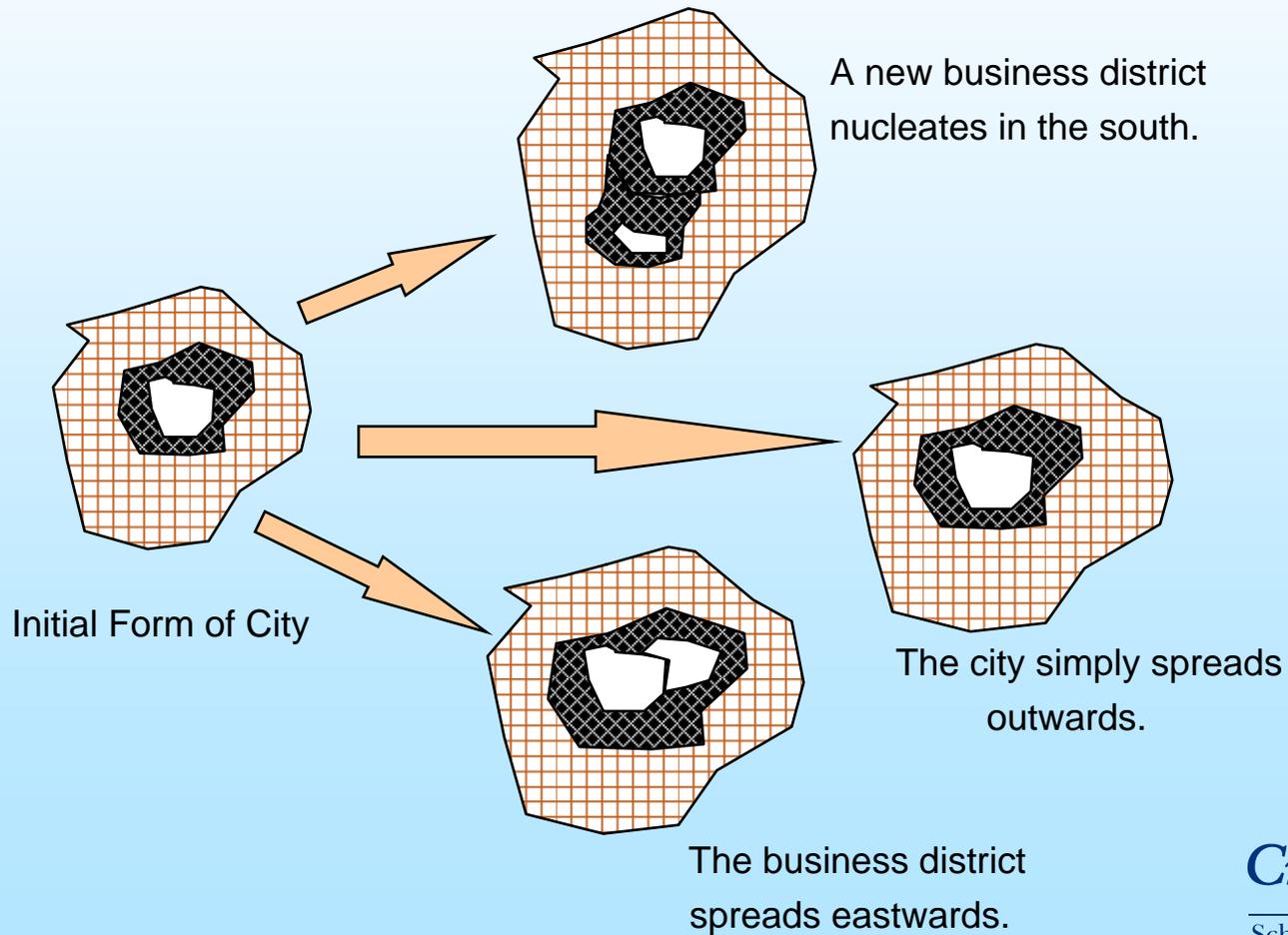
Prediction of possible Regimes.....

$$dx/dt = G(x,y)$$
$$dy/dt = H(x,y)$$

Y

Cyclic Attractor

Point Attractor

Point Attractor

Separatrices

Point Attractor

Cyclic Attractor

Cyclic Attractor

Cyclic Attractor

Point Attractor

Point Attractor

X

Change parameter values, and the map may change
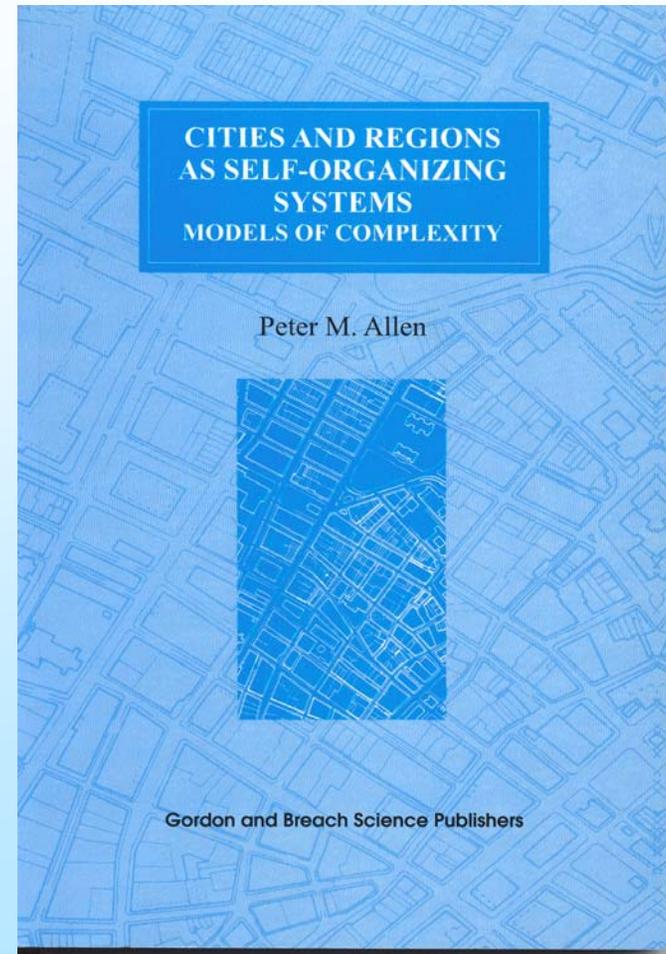
Changed TOPOLOGY = Bifurcation

- Different possible regimes of operation exist - for the same mechanisms/rules

- They may differ qualitatively and this may be what matters

- Instead of trying to get 2% changes in variables, try to get the "qualitative" result right…..

Urban Evolution

A new business district nucleates in the south.

The city simply spreads outwards.

Initial Form of City

The business district spreads eastwards.

Self-Organising, dynamic spatial models:

- ISBN -9056990705 and 9056990713

- Urban, Regional models

- Integrates land-use and transport

- Also, links to natural resources (water, land, soils etc.)

- Sustainable Development

CITIES AND REGIONS
AS SELF-ORGANIZING
SYSTEMS
MODELS OF COMPLEXITY

Peter M. Allen

Gordon and Breach Science Publishers

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Spatial Dynamic Urban Models

- Different types of actor at each zone, with characteristic needs to be fulfilled

- These characteristic needs are stable, but the behaviour of actors depends on the changing circumstances

- The spatial distributions of the different types of job and different kinds of people affect each other as the potential for housing demands, commercial activities and for travel affect and are affected by transportation and land-use…….

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The Interaction mechanisms of "Brussaville"..

**Transport Networks
Road, Rail, Buses,
trams, walking…**

**Flows on all links of
all networks an
dynamic output
of the model….**

**Impacts of changed
infrastructure, with
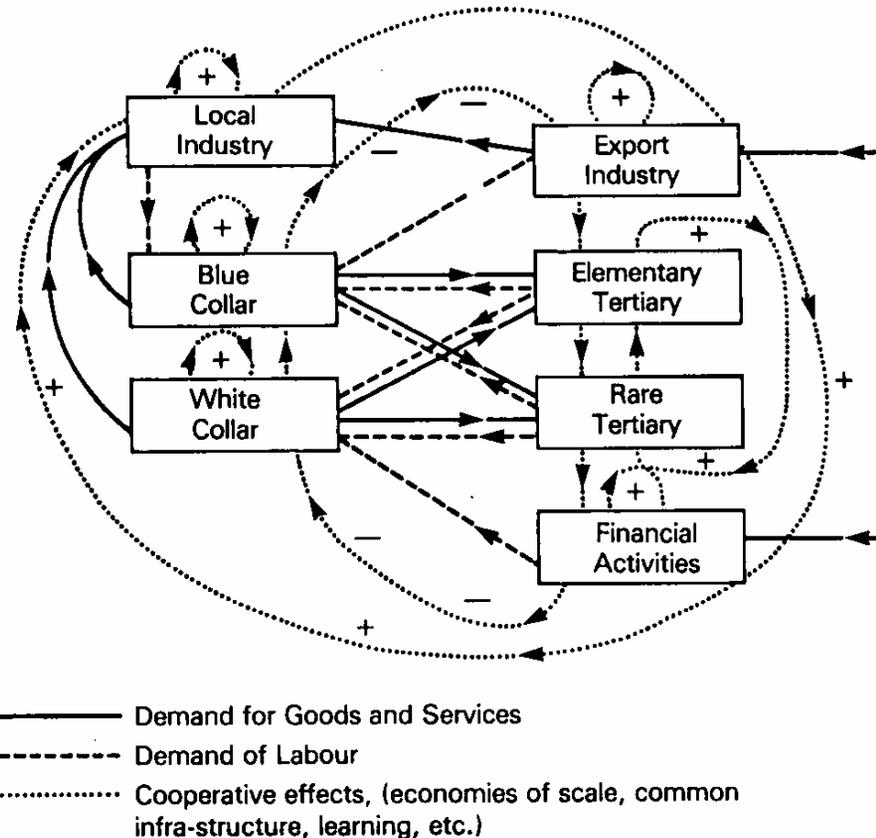feedbacks…..**

Figure 9.1 The scheme of interaction for an intraurban evolution.
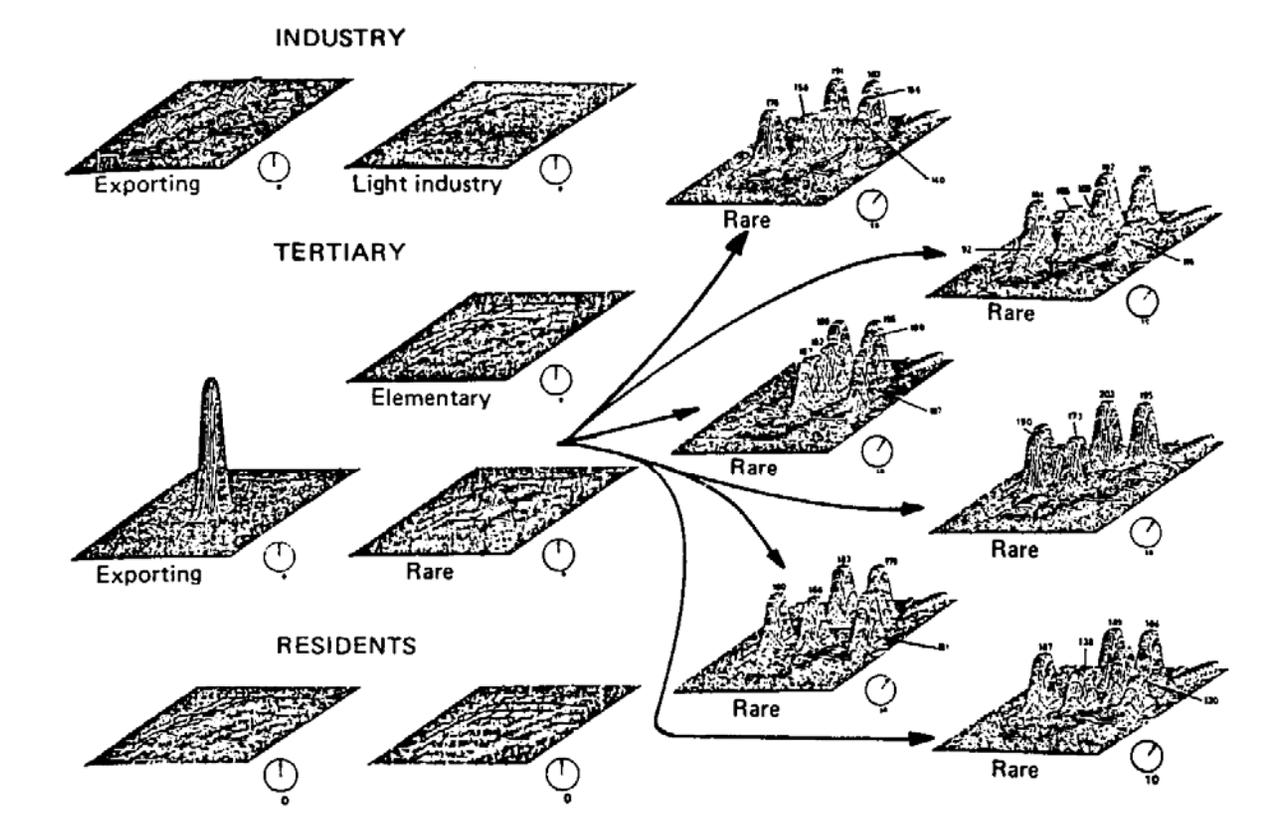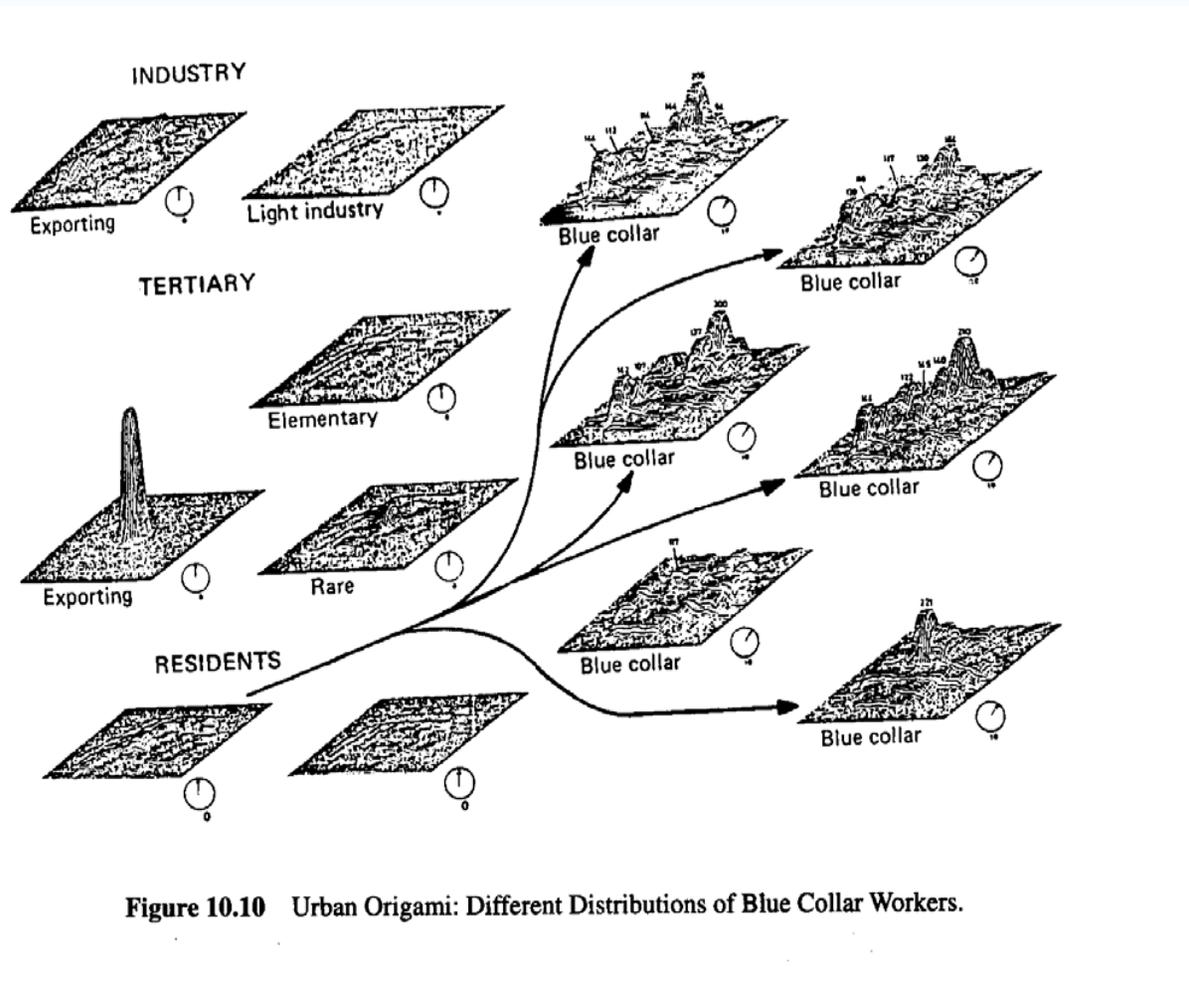
Urban Origami - for Long Range Tertiary

Figure 10.11   Urban Origami: Different Distributions of Retail Employment

Urban Origami - For Blue Collar residents

Figure 10.10   Urban Origami: Different Distributions of Blue Collar Workers.

"NOISE" Affects the results !

- For all of these systems the "noise" present in the variables matters.

- The non-linearities can amplify small differences the values of variables, leading to "SELF-ORGANIZATION"

- Microdiversity in the local populations can also lead to different adaptive responses to changing conditions.