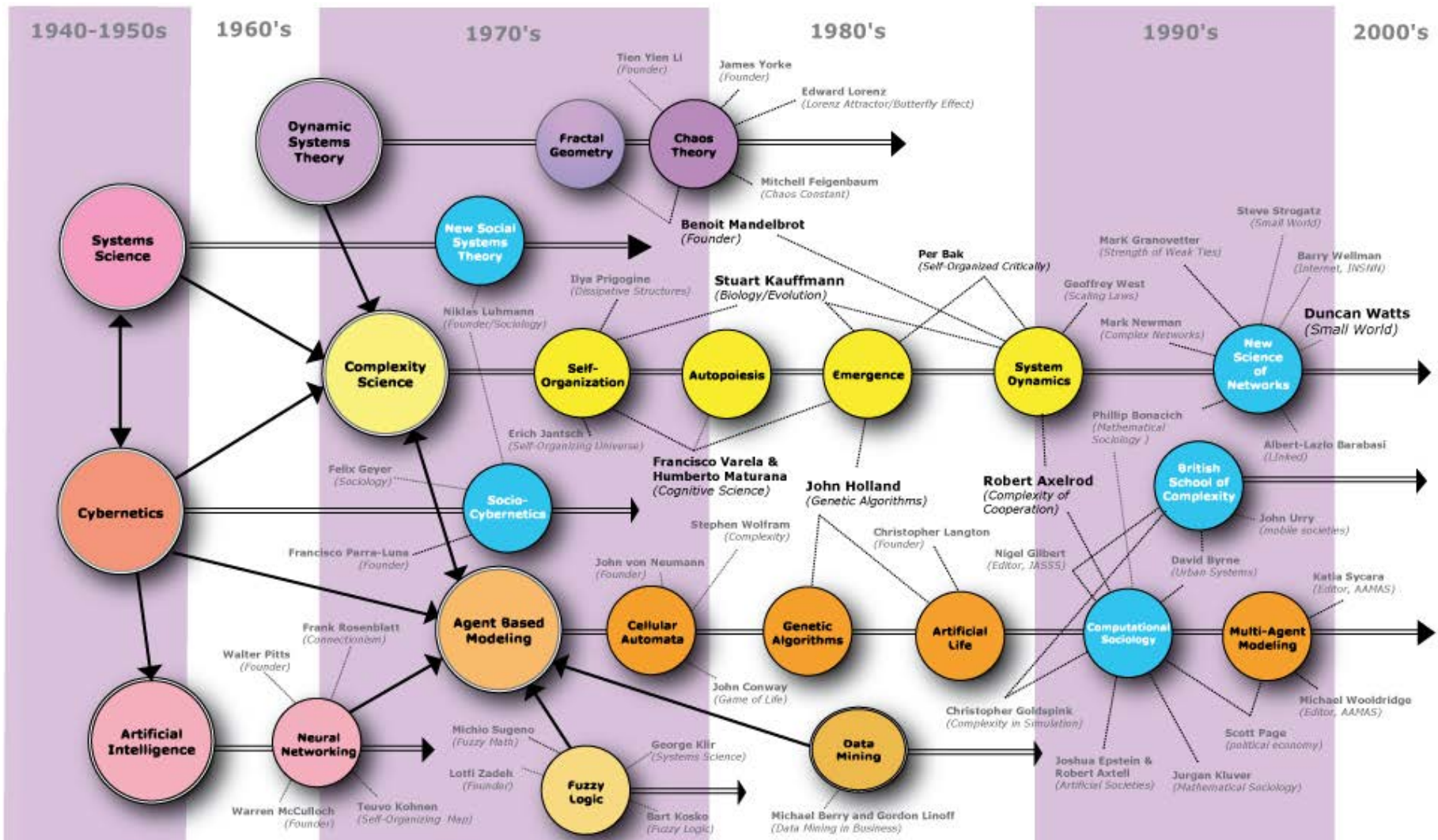
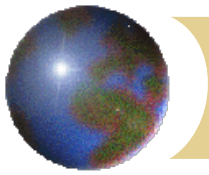


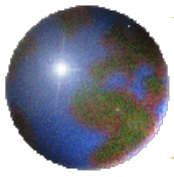
System Science(s): Study of systems





System Dynamics

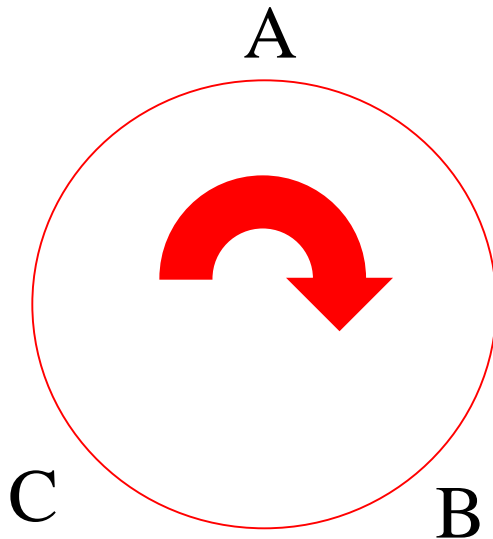
“An approach to understanding the behaviour of complex systems over time. It deals with internal feedback loops and time delays that affect the behaviour of the entire system. What makes using system dynamics different from other approaches to studying complex systems is the **use of feedback loops and stocks and flows**. These elements help describe how even seemingly simple systems display baffling nonlinearity.” (Wikipedia, 2014)



Linear Causality

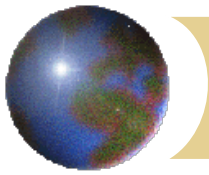


Circular Causality



Feedback: shows how actions can reinforce (positive feedback) or counteract (balance through negative feedback) each other

Variables are organized in a circle or loop of cause-effect relationship called a “feedback process”



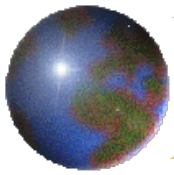
Feedback Processes

Reinforcing (R) or Amplifying

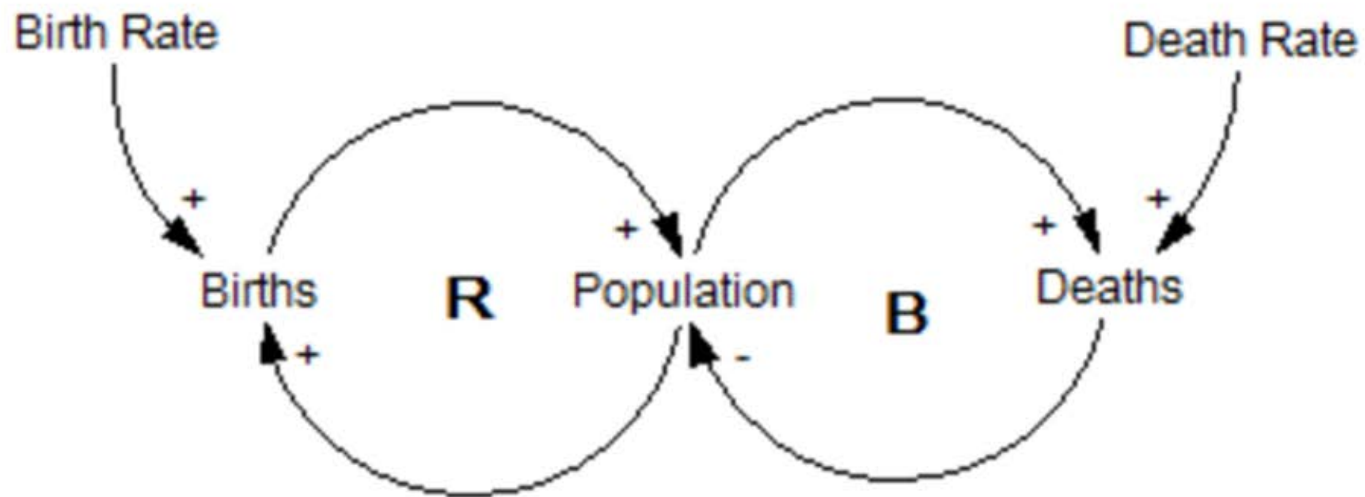
- Cause dramatic growth or collapse
- Amplifies change
- Snowballing effect
- Make something greater or less
- Accelerating growth or decline
- “Vicious cycles”, “self fulfilling prophecies”, “Virtuous cycles”

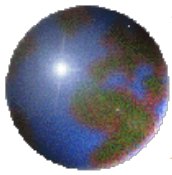
Balancing (B) or Stabilizing

- Operates when there is a goal oriented behavior (implicit or explicit)
- Keep things under control
- Limit dramatic growth
- Ensure that systems fulfills its purpose
- Seeks equilibrium and stability
- Self correction to keep goal or target

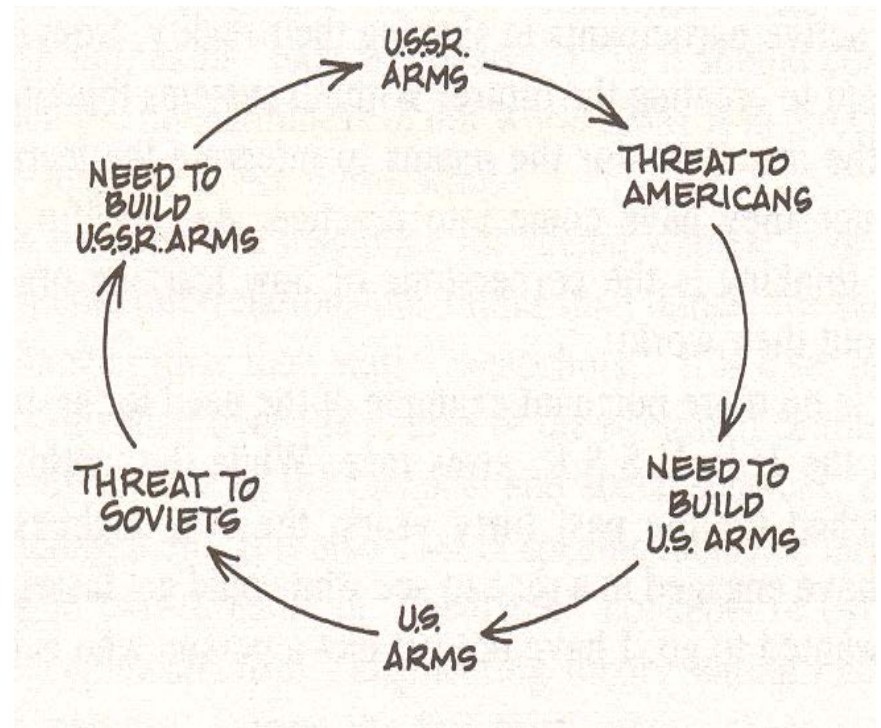
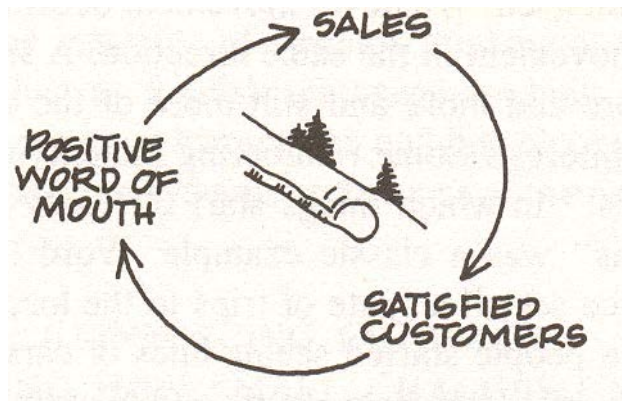


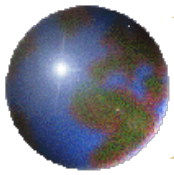
Causal Loop Diagrams (CLDs)



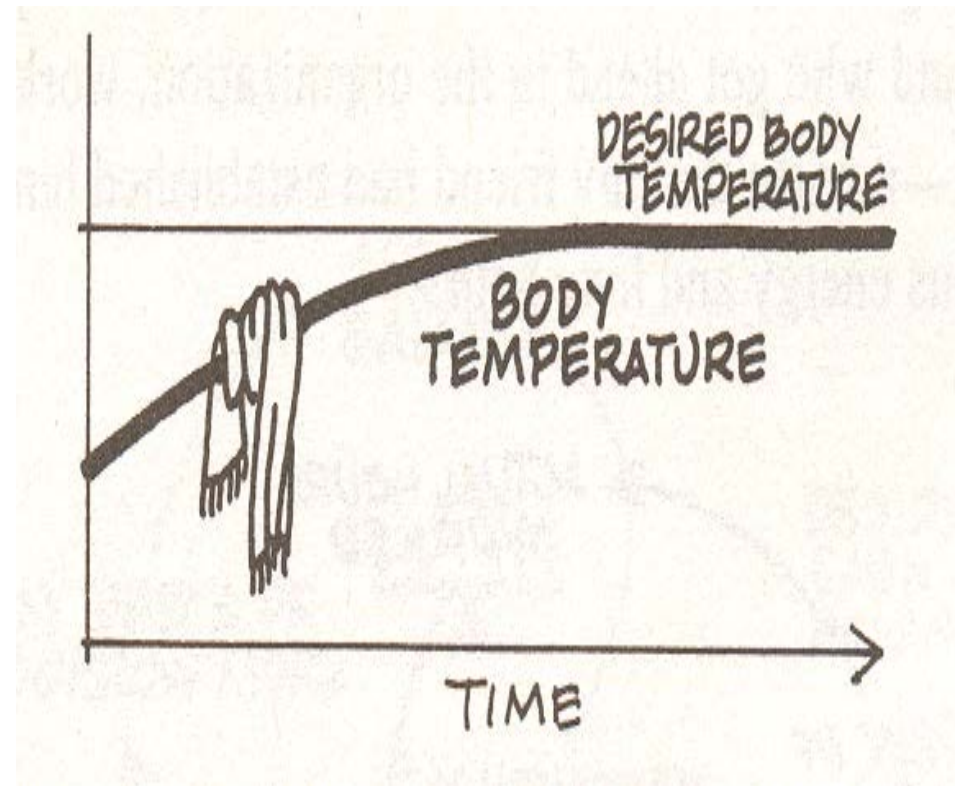
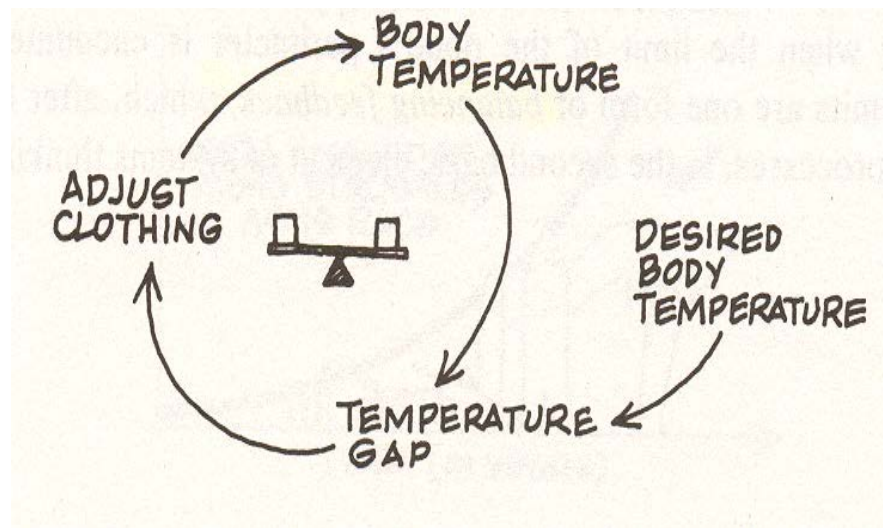


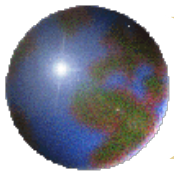
Reinforcing Feedback



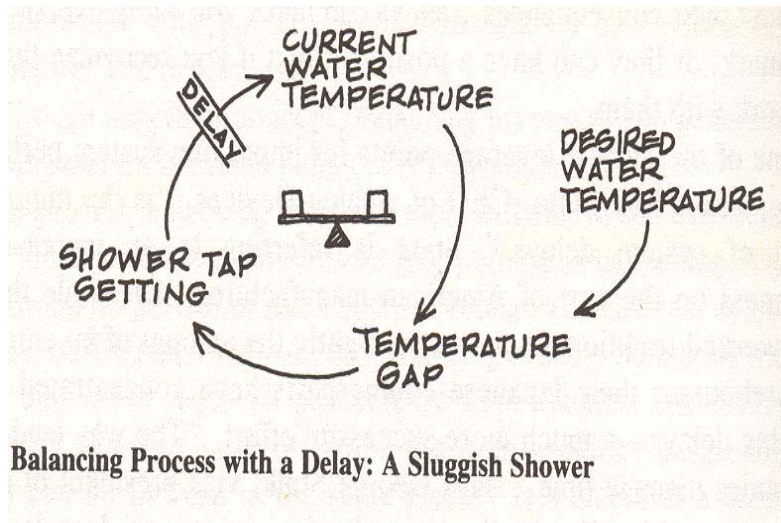


Balancing Feedback

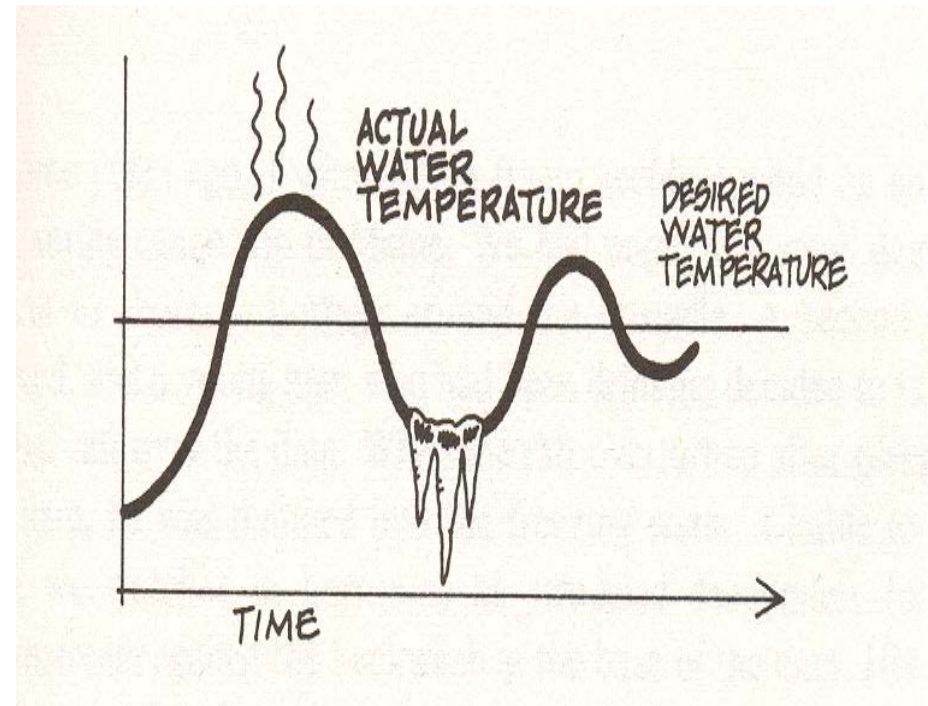


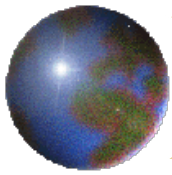


*Delay = interruption between actions
and their consequences*

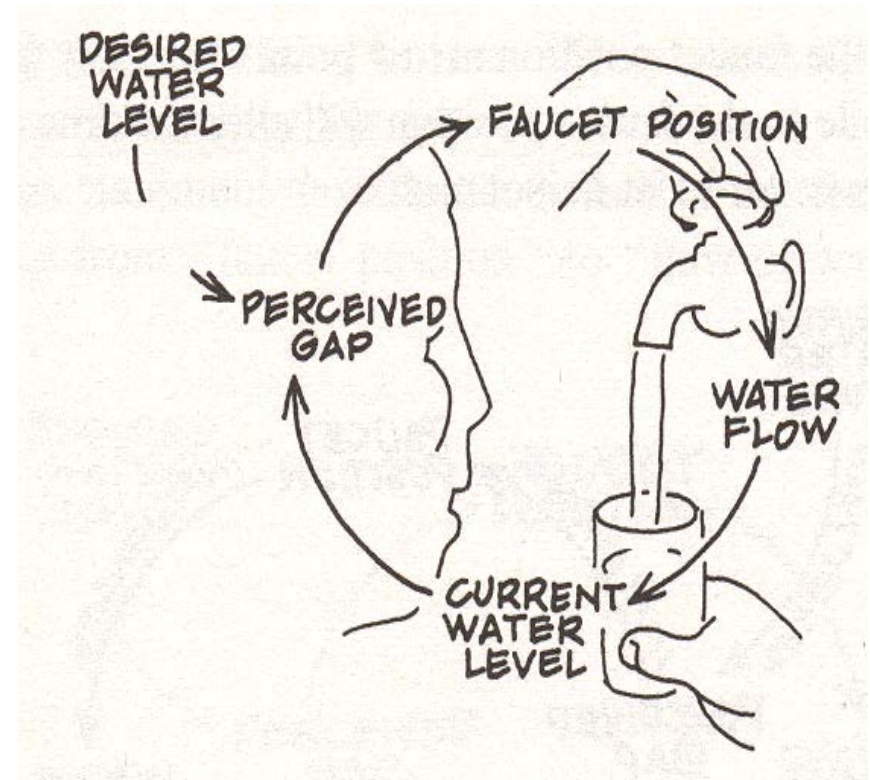
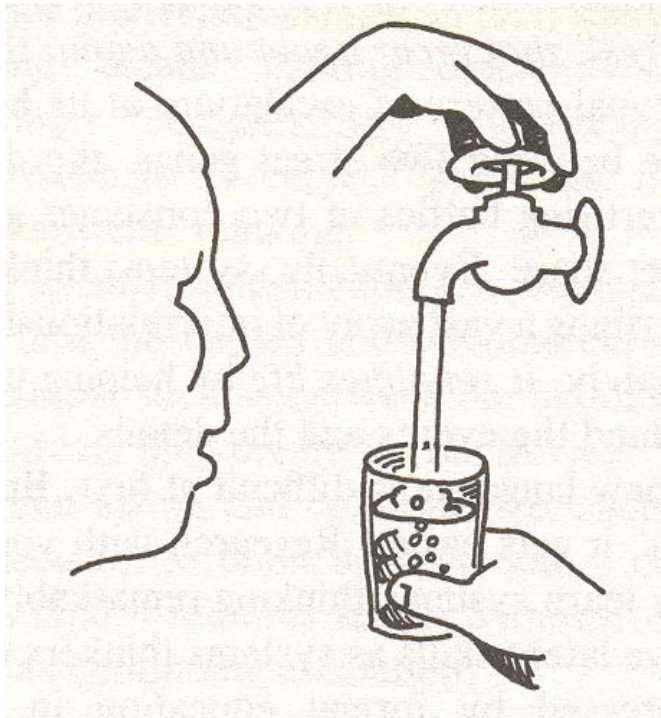


Balancing Process with a Delay: A Sluggish Shower

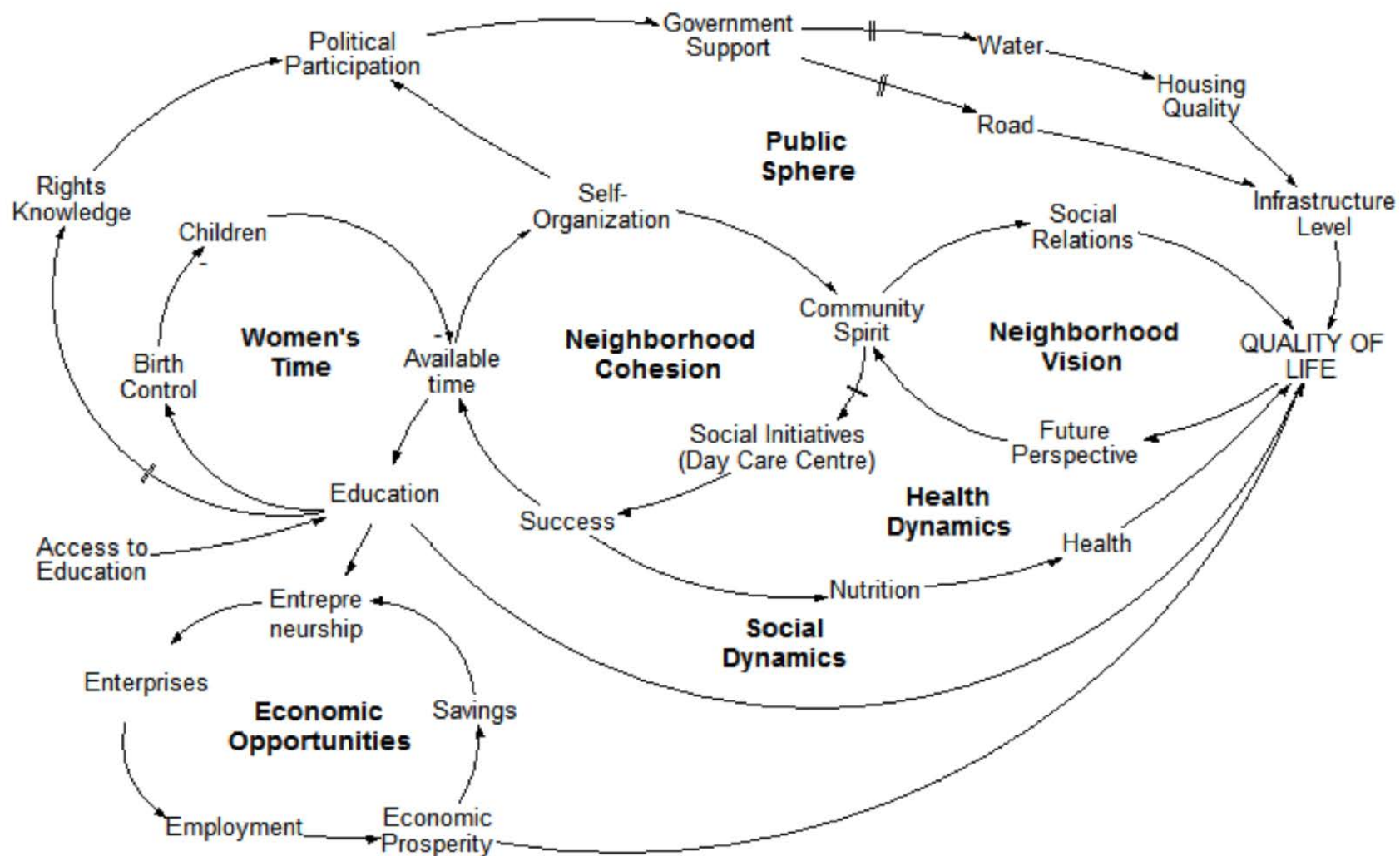
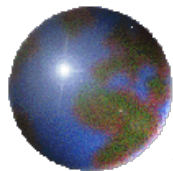


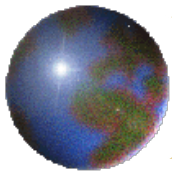


“I am filling a glass of water”

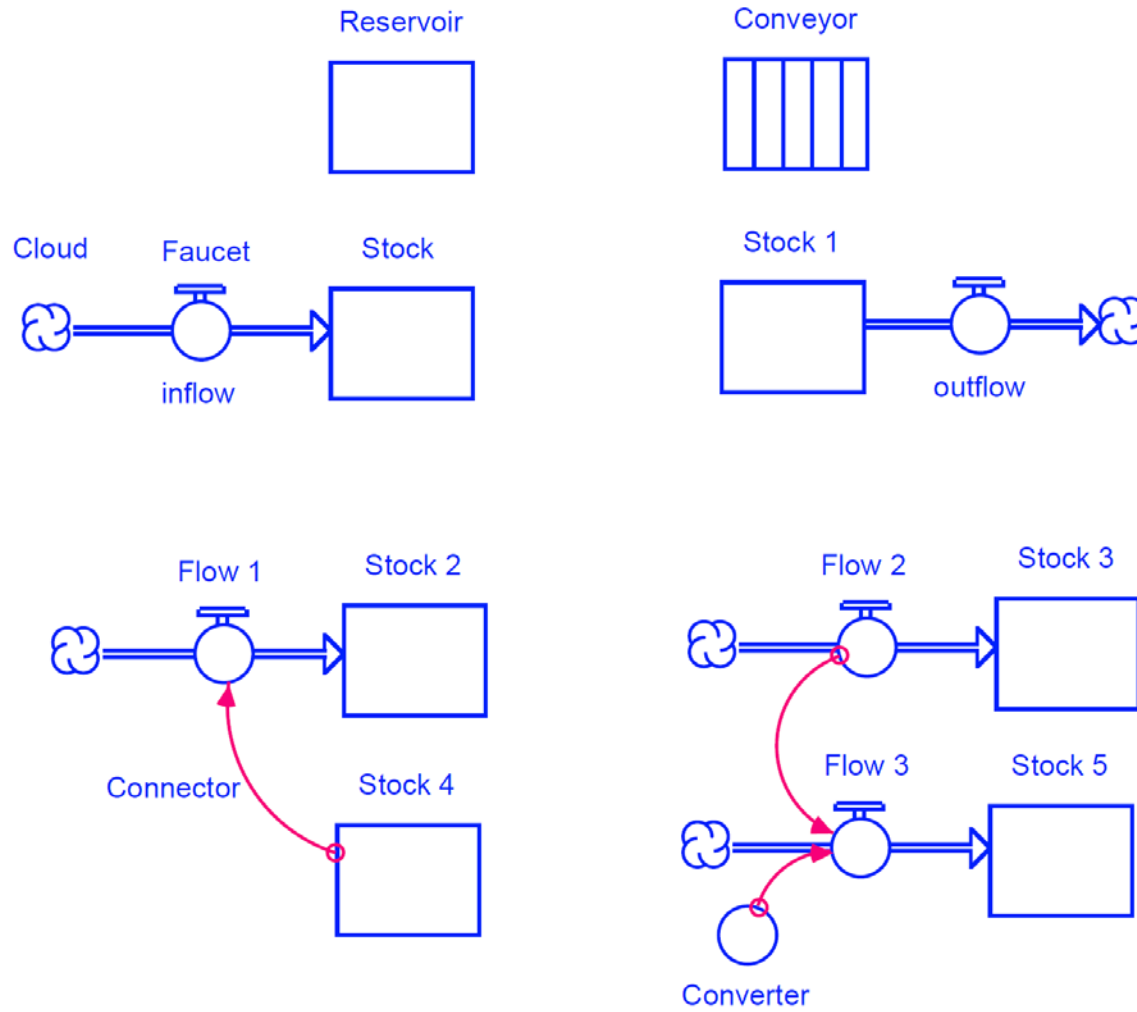


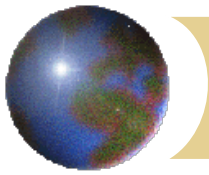
From *The 5th Discipline* by Peter Senge (1990)





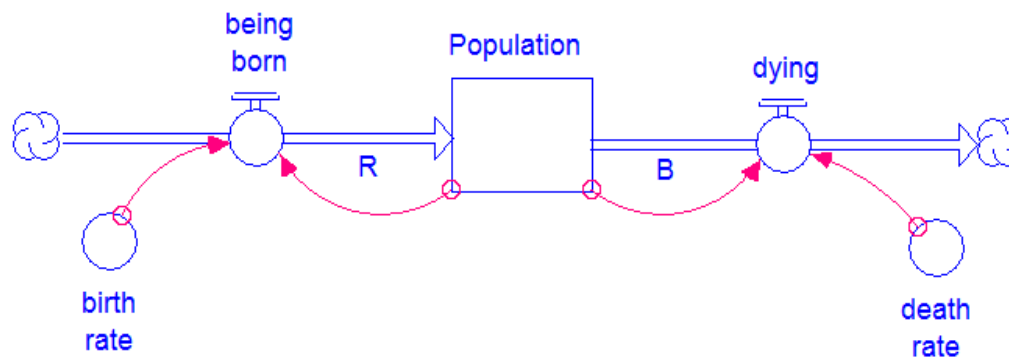
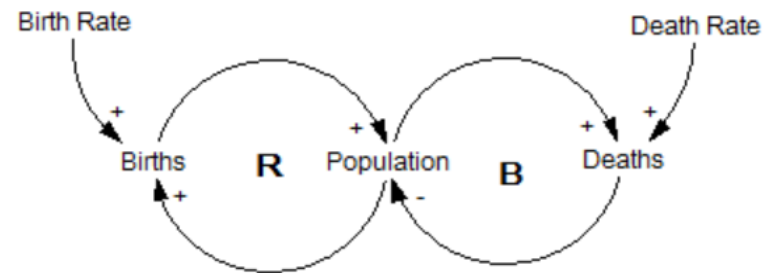
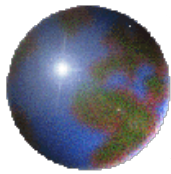
Stock and Flow Diagrams

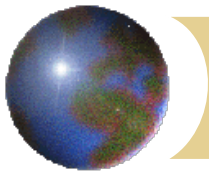




Flow and Stock

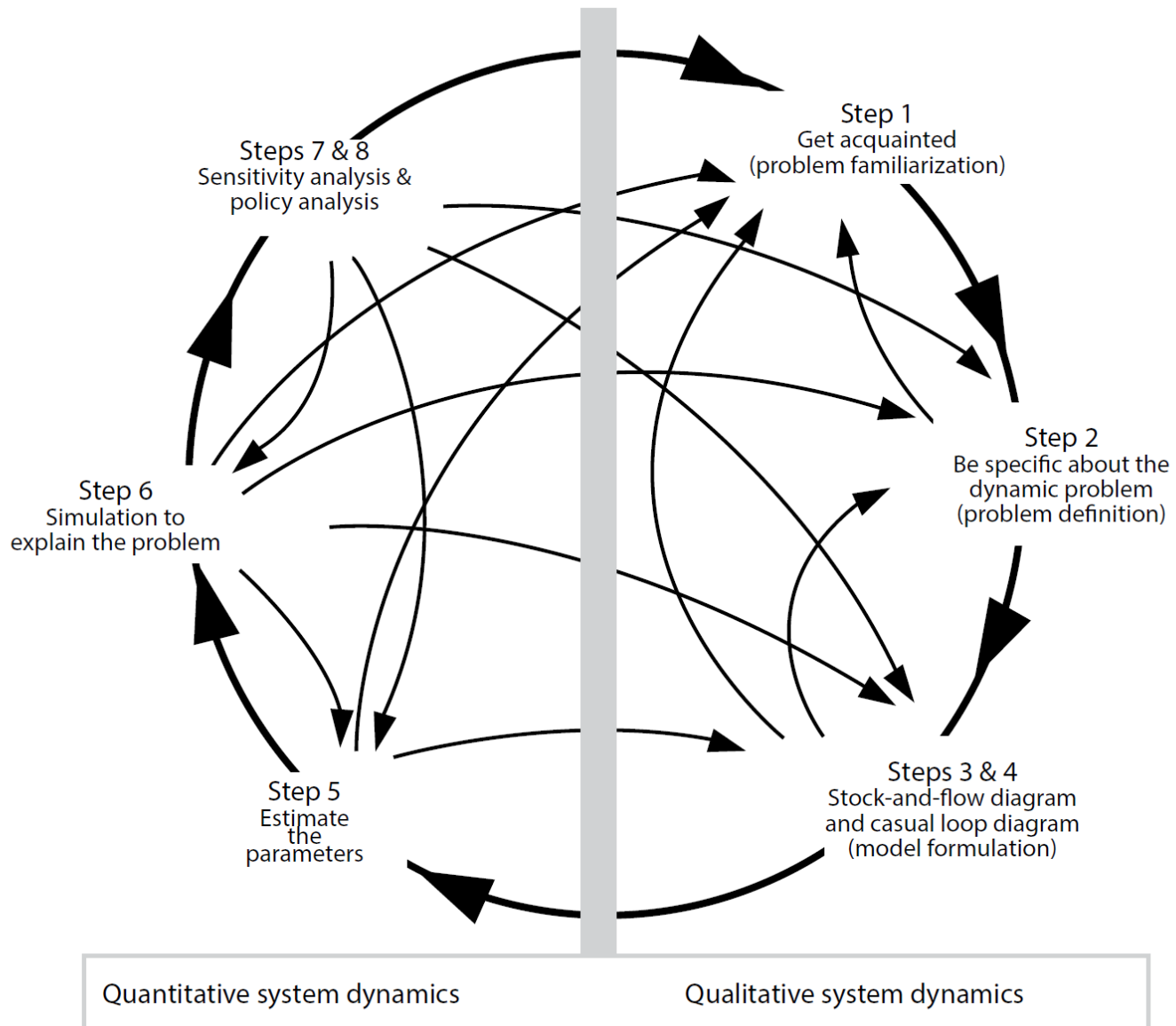
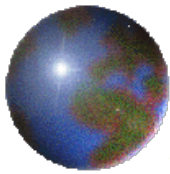
- ❖ Stock: Anything that accumulate and can be measured at one point in time (water in bathtub or behind a dam, population, wood in the forest, etc.)
- ❖ Flow: Anything that changes over time (number of births, inflation rate, etc.). Inflows and outflows
- ❖ Stock and flow obey laws of conservation and accumulation

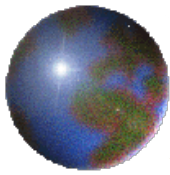




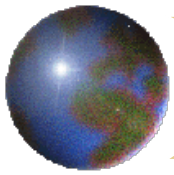
Using iThink or Stella

- ✚ Trademark of Isee systems
(www.iseesystems.com)
- ✚ Introduction to Systems Thinking by Richmond (2004 a,b).
- ✚ Other SD software include Vensim and Powersim.

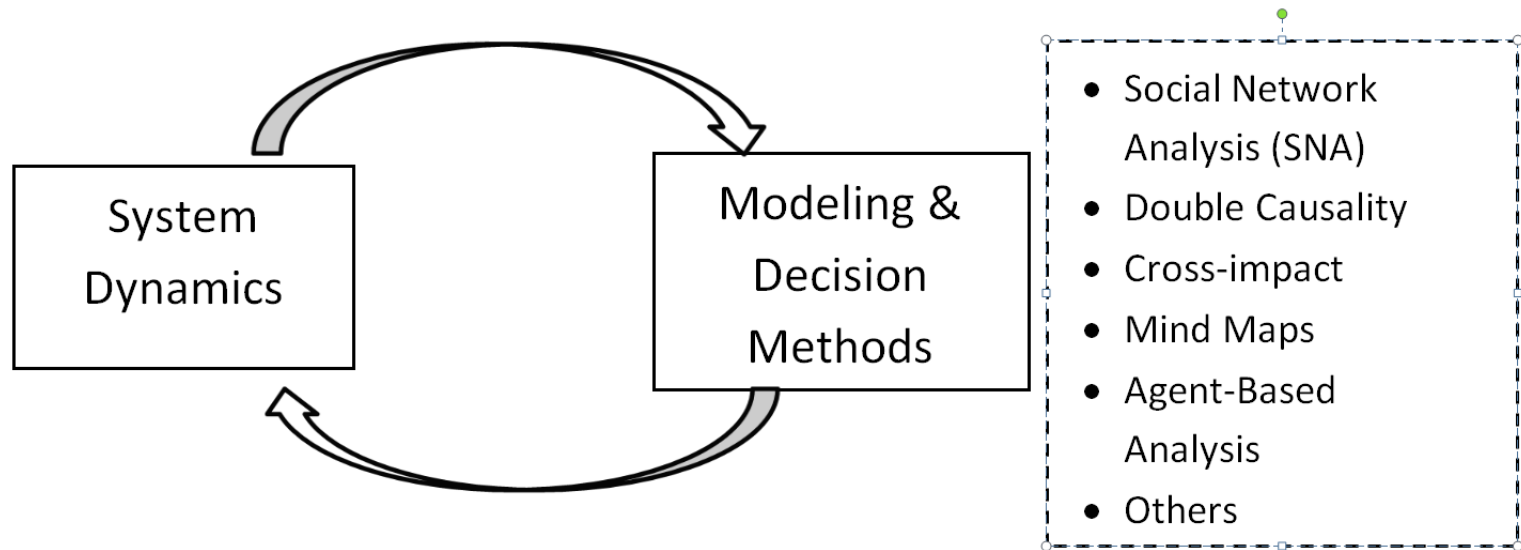




	Tangible	Intangible
Stocks	Populations (male, female) Food Energy Resources Land Houses Labor (jobs) Trees Roads, traffic, vehicles Water, Pollutants Cash Cattle Equipment	Poverty or wealth Quality of life Happiness Health Hunger Quality Anger Satisfaction Confidence Morale Motivation Attractiveness Leadership
Flow	Hiring, lay-off Saving Producing Being born, dying Constructing Depreciating Being infected Adopting Earning, spending Pumping, recharging Evaporating, infiltrating	Learning Growing Becoming aware Contributing Leading Managing Changing behavior Liking, disliking Becoming sustainable Understanding Assuming



Mixed Modeling Methods



Climate change linkages and impacts

Impact of climate change on poverty

- Poor hit earliest and hardest with the least capacity to adapt. Climate change may lead to:
- Loss of habitats & biodiversity,
- Loss of livelihoods / new opportunities, Increased frequency / severity of natural disasters, flooding and extreme weather,
- Water scarcity & desertification,
- Conflict, civil unrest and migration,
- Health impacts & food insecurity.
- Complex trade-offs: e.g. biofuels could boost or undermine livelihoods of poor, carbon markets could reduce or entrench poverty.

Impact of climate change on globalisation

- The impacts of carbon trading and the shift towards a low carbon economy especially in energy, transport, foodstuffs, manufacturing, construction & tourism markets,
- Localisation of supply chains & markets due to higher transport costs,
- Increased risk, uncertainty & market volatility, Disruption to agriculture & infrastructure,
- Failure to address climate change undermines global economy and support for globalisation processes.

Impact of climate change on engineering

- New markets and opportunities in renewable energy, alternative fuels, energy conservation & waste reduction,
- New research / innovation opportunities,
- Disaster preparedness and relief and post-disaster reconstruction,
- Low carbon economy especially in energy, infrastructure & construction markets.

Impact of poverty on climate change

- Farming, energy, transport, urbanisation and development choices of developing nations are critical if global CO2 reduction targets are to be met especially in rapidly industrialising economies (Brazil, Russia, India & China).
- Global carbon trading and emissions targets must recognise the needs and rights of the poor and the obligations of industrialised nations.

Poverty linkages and impacts

Impact of poverty on globalisation

- The responsibility to act ethically, contribute to poverty reduction and involve poor in decision making is becoming recognised by global corporations,
- Failure to act responsibly or to address poverty undermines support for (current models of) globalisation.
- Globalisation criticised by international development & trade reformers.

Impact of poverty on engineering

- Requires low cost solutions that are appropriate to cultural, political, social and economic environment,
- Requires participation of the poor and local knowledge,
- Developing countries are often high risk / high return markets.

Impact of globalisation on climate change

- International supply chains increase energy and transport impacts,
- Reduced production costs increase waste and consumerism fuelling carbon emissions
- Environmental impacts displaced to less developed country (LDC) production centres.

Impact of globalisation on poverty

- Social, legal & environmental safeguards often lower in less developed countries (LDCs),
- Offers economic opportunities esp. in natural resources & agriculture, tourism, manufacturing and fair-trade goods,
- LDC economies vulnerable to capital flight and brain drain, trade rules disadvantage LDCs and undermine national sovereignty.

Globalisation linkages and impact

Impact of globalisation on engineering

- Growth in LDC markets esp. in utilities, infrastructure & the extractive industries,
- International supply chains promote technology transfer & standardised systems,
- Growth in labour mobility, access to knowledge.

Impact of engineering on climate change

- Transport, energy, agriculture, infrastructure and manufacturing choices determine impacts,
- Engineering and innovation key to mitigation and adaptation,
- Engineering key to disaster preparedness and reconstruction.

Impact of engineering on poverty

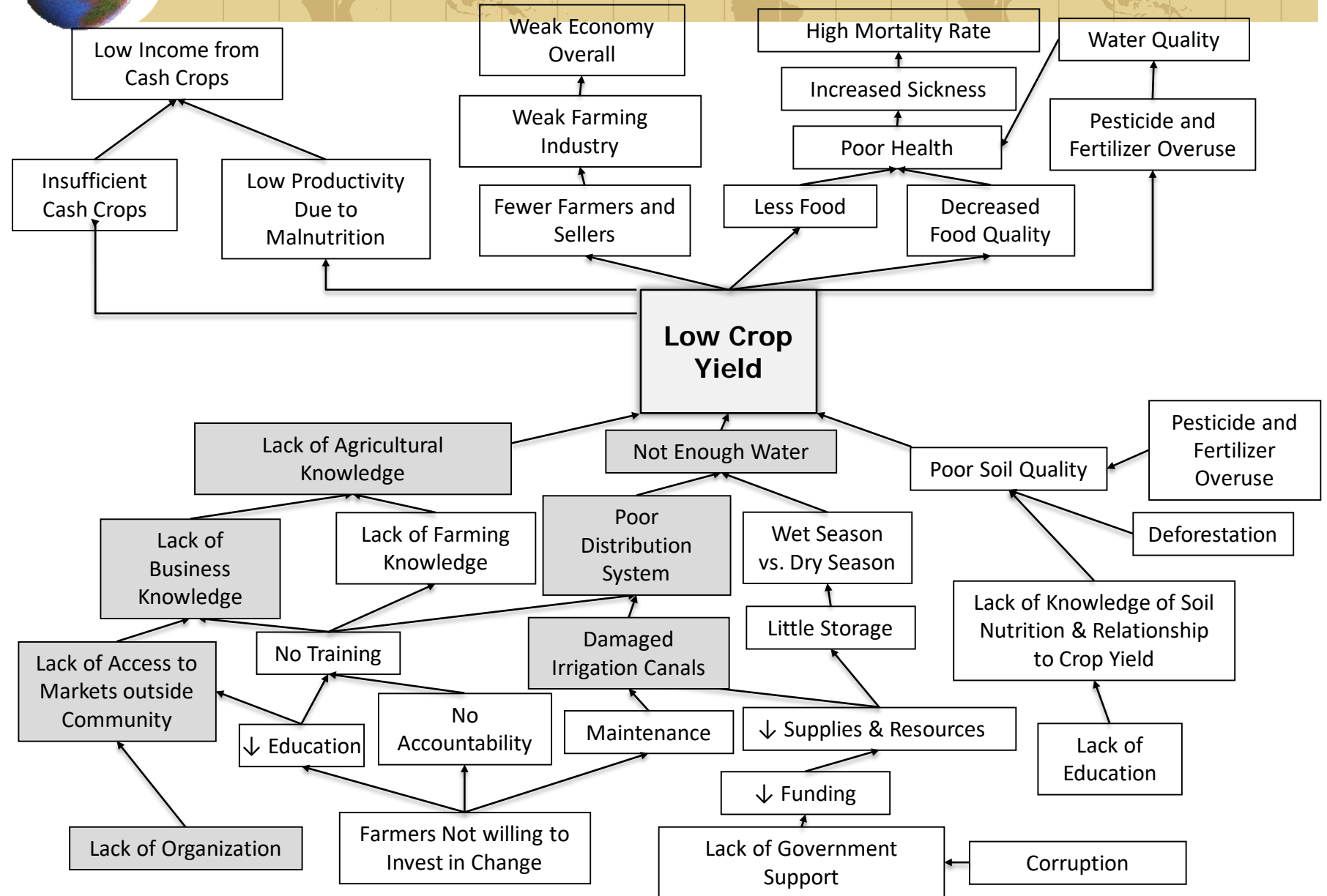
- Engineering key to providing pro-poor energy, transport, shelter, health and water products and services,
- Platform infrastructure and technologies provide an enabling environment for growth,
- Engineering supply chains and technology transfer offer poverty reduction opportunities.

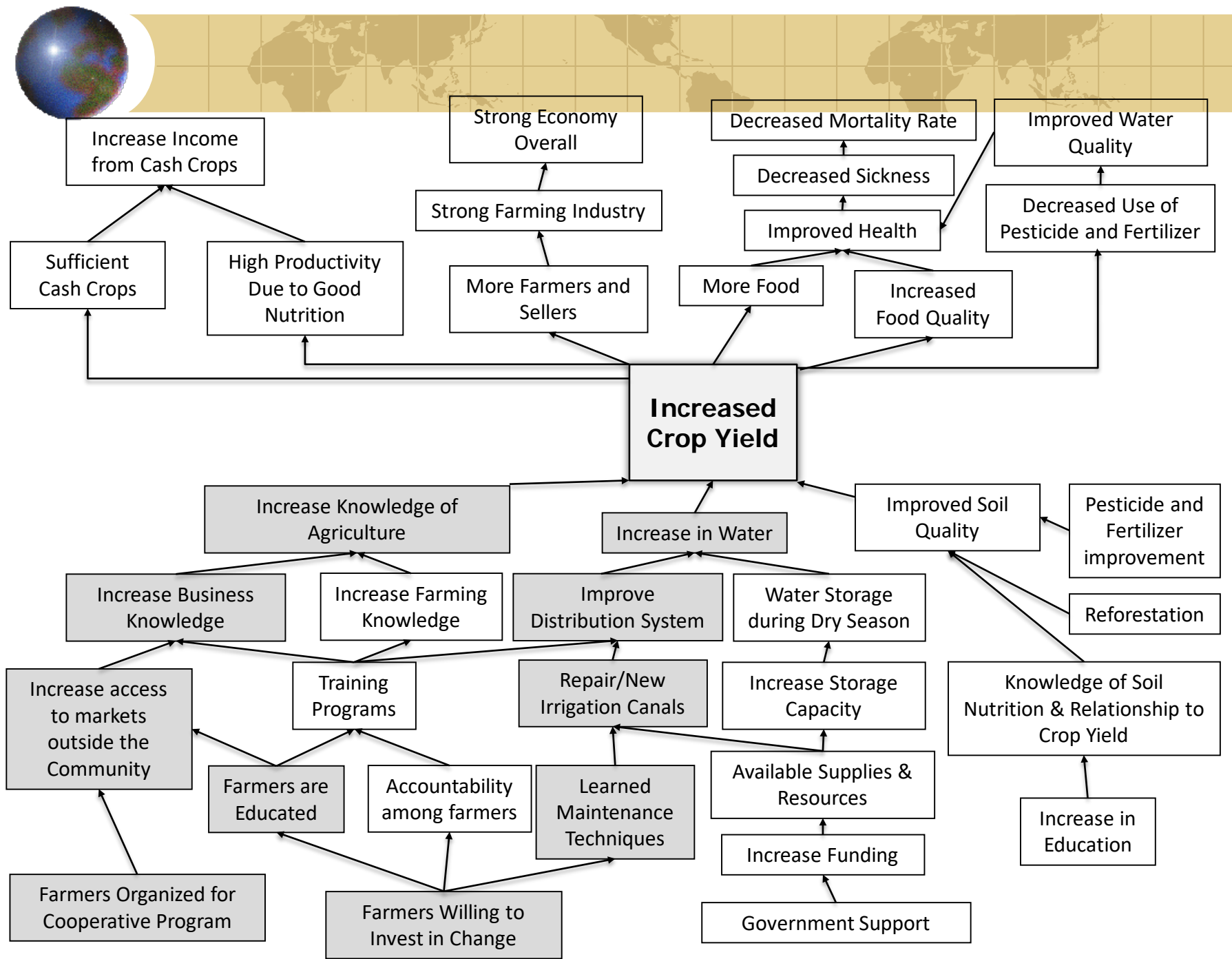
Impact of engineering on globalisation

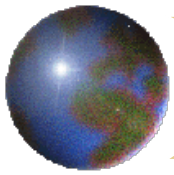
- Engineering knowledge and innovation especially in transport, energy, manufacturing and ICT are the drivers behind economic integration and globalisation,
- Sustainability and climate change will force a revised model of engineering and globalisation.

Engineering linkages and impacts

Water	Impact of Water on All Children Reading	Impact of water on governance	Impact of water on empowering agriculture	Impact of water on Saving Lives at Birth
Impact of All Children Reading on Water	All Children Reading	<div> <div></div> <div></div> </div>		
Impact of governance on water	<div> <div></div> <div></div> </div>	Governance		
Impact of powering agriculture on water			Powering Agriculture	
Impact of Saving Lives at Birth on water				Saving Lives at Birth







"The significant problems we face today cannot be solved at the same level of thinking we were at when we created them."

Albert Einstein

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