CE102: Environmental Studies

By

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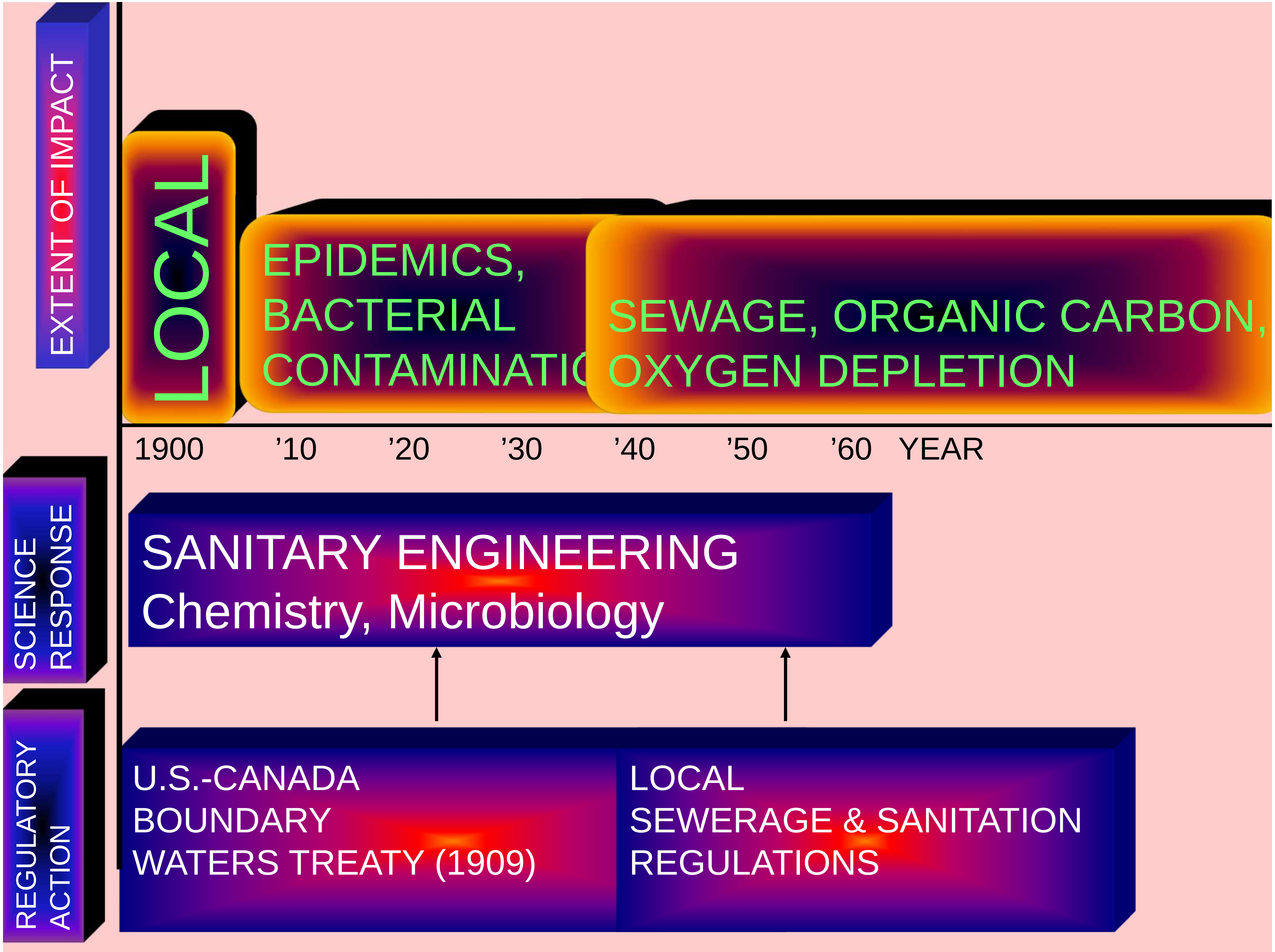
Explosion of Environmental Issues

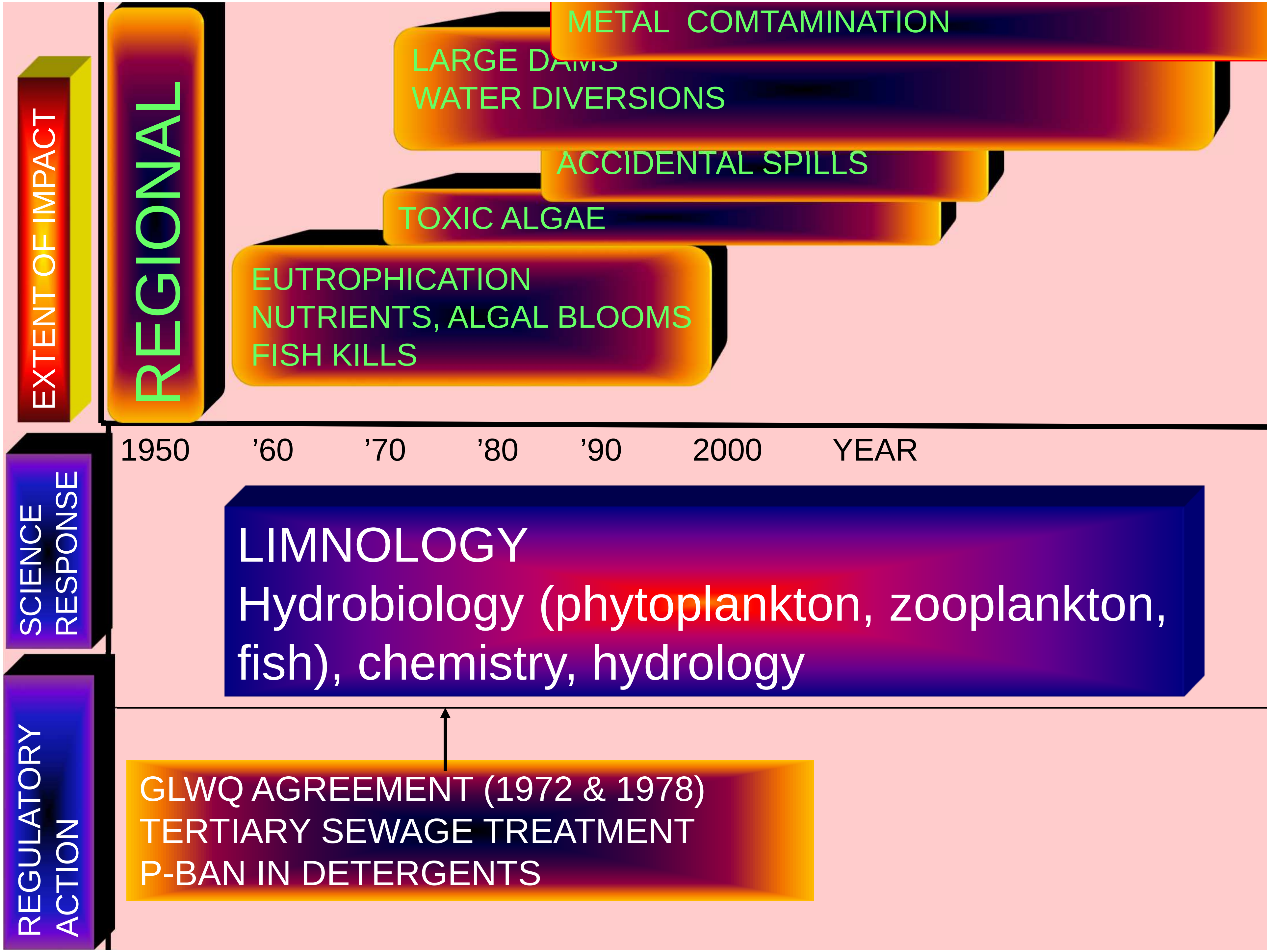
- From Few to Many, From Local to Global
- Science Response
- Response of Regulatory Agencies

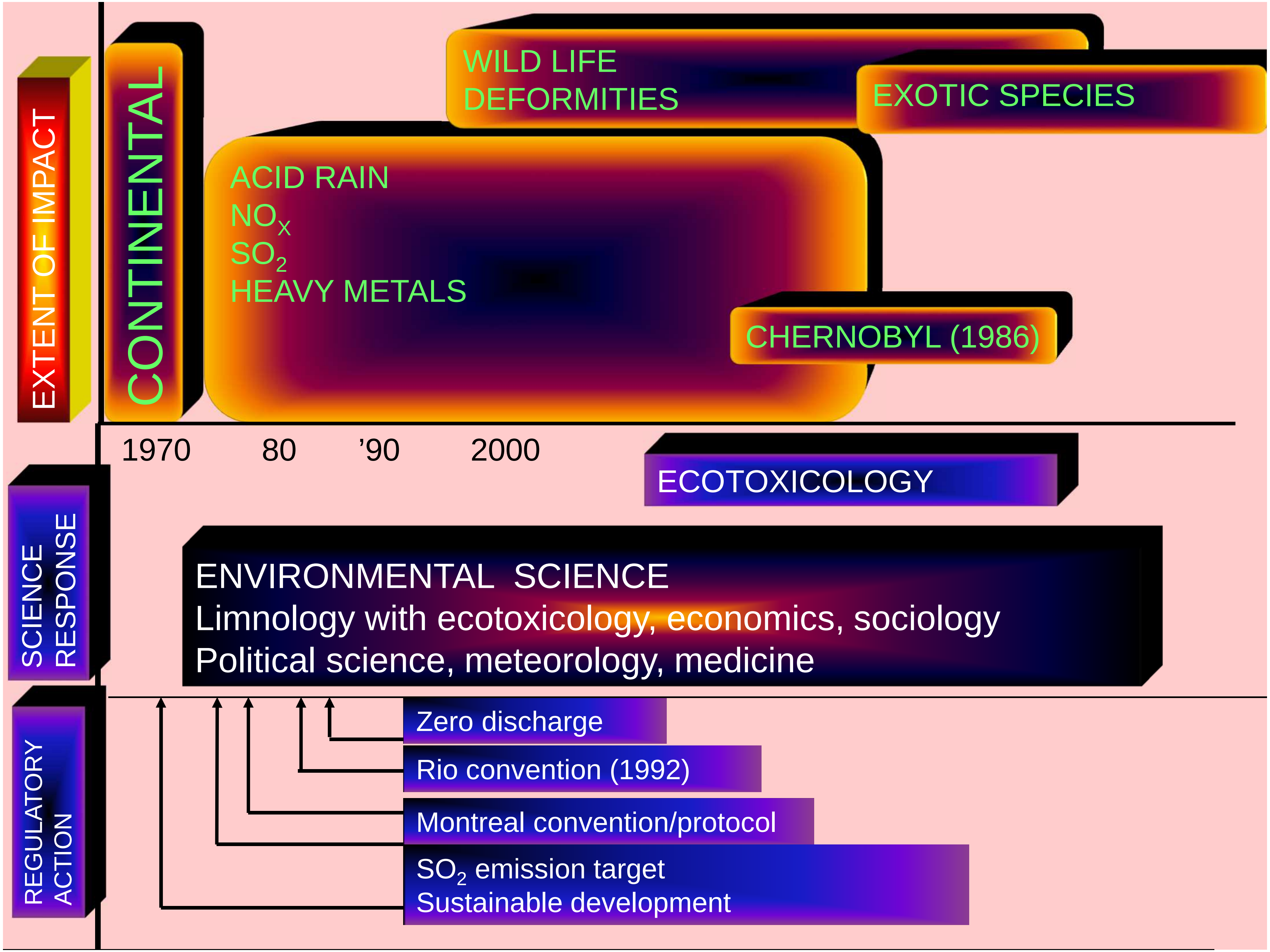
Explosion of Environmental Issues

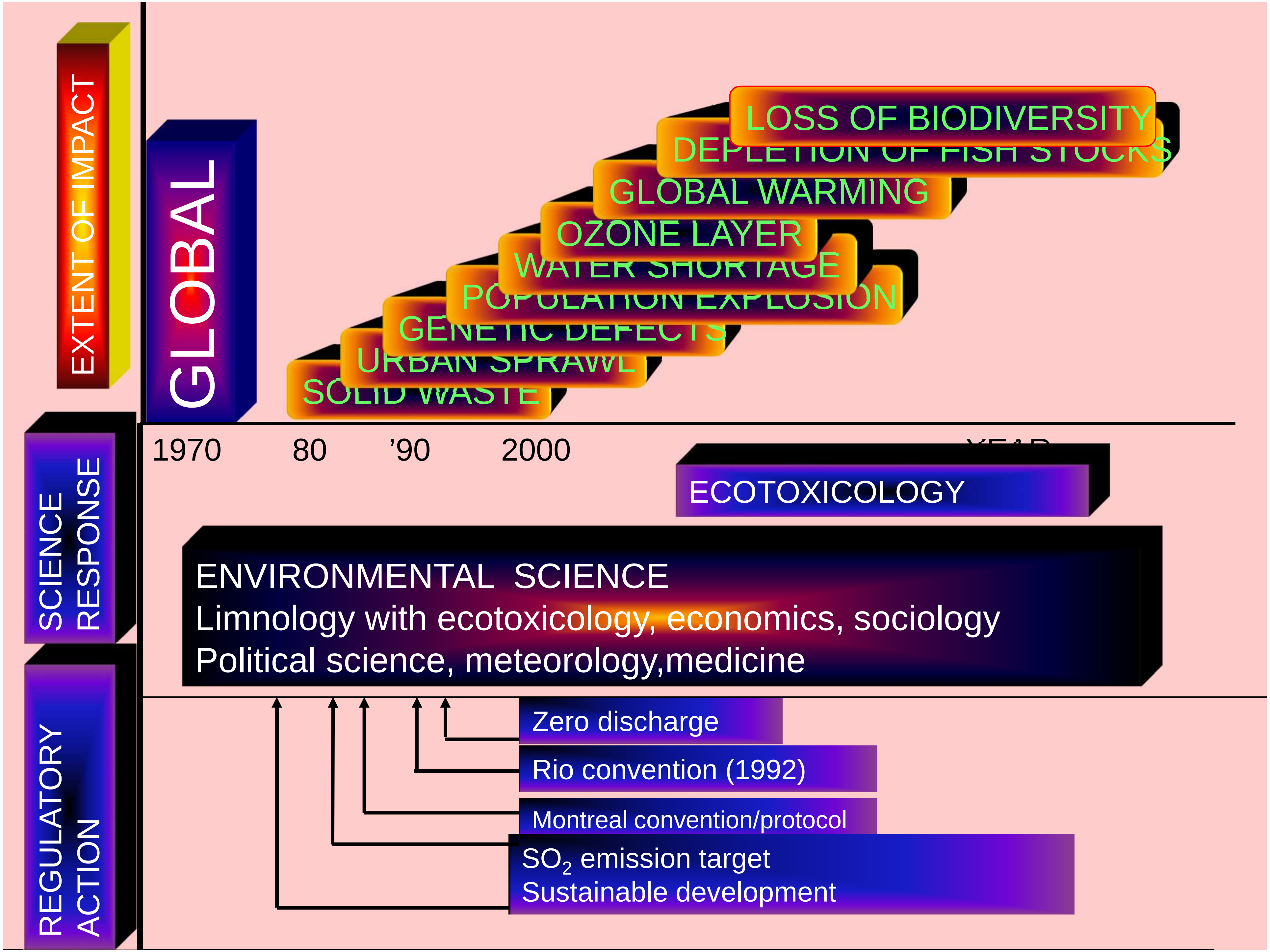
Spatial Scales

- Micro-scale (10 to 100 m) and Middle-scale (100 to 500 m)
- Neighborhood scale (500 m to 4 km)
- Urban scale (4 to 100 km to 1,000 km)
- Continental scale (1,000 to 10,000 km)
- Global scale (> 10,000 km)


EXTENT OF IMPACT
LOCAL
EPIDEMICS, BACTERIAL CONTAMINATIO
SEWAGE, ORGANIC CARBON, OXYGEN DEPLETION
1900
'10
'20
'30
'40
'50
'60
YEAR
SCIENCE RESPONSE
SANITARY ENGINEERING
Chemistry, Microbiology
REGULATORY ACTION
U.S.-CANADA BOUNDARY WATERS TREATY (1909)
LOCAL SEWERAGE & SANITATION REGULATIONS


EXTENT OF IMPACT
REGIONAL
METAL COMTAMINATION
LARGE DA
WATER DIVERSIONS
ACCIDENTAL SPILLS
TOXIC ALGAE
EUTROPHICATION
NUTRIENTS, ALGAL BLOOMS
FISH KILLS
1950
'60
'70
'80
'90
2000
YEAR
SCIENCE RESPONSE
LIMNOLOGY
Hydrobiology (phytoplankton, zooplankton, fish), chemistry, hydrology
REGULATORY ACTION
GLWQ AGREEMENT (1972 & 1978)
TERTIARY SEWAGE TREATMENT
P-BAN IN DETERGENTS


EXTENT OF IMPACT
CONTINENTAL
WILD LIFE
DEFORMITIES
EXOTIC SPECIES
ACID RAIN
NO_X
SO_2
HEAVY METALS
CHERNOBYL (1986)
1970
80
'90
2000
ECOTOXICOLOGY
SCIENCE
RESPONSE
ENVIRONMENTAL SCIENCE
Limnology with ecotoxicology, economics, sociology
Political science, meteorology, medicine
REGULATORY
ACTION
Zero discharge
Rio convention (1992)
Montreal convention/protocol
SO_2 emission target
Sustainable development


EXTENT OF IMPACT
GLOBAL
LOSS OF BIODIVERSITY
DEPLETION OF FISH STOCKS
GLOBAL WARMING
OZONE LAYER
WATER SHORTAGE
POPULATION EXPLOSION
GENETIC DEFECTS
URBAN SPRAWL
SOLID WASTE
1970
80
'90
2000
SCIENCE RESPONSE
ECOTOXICOLOGY
ENVIRONMENTAL SCIENCE
Limnology with ecotoxicology, economics, sociology
Political science, meteorology,medicine
REGULATORY ACTION
Zero discharge
Rio convention (1992)
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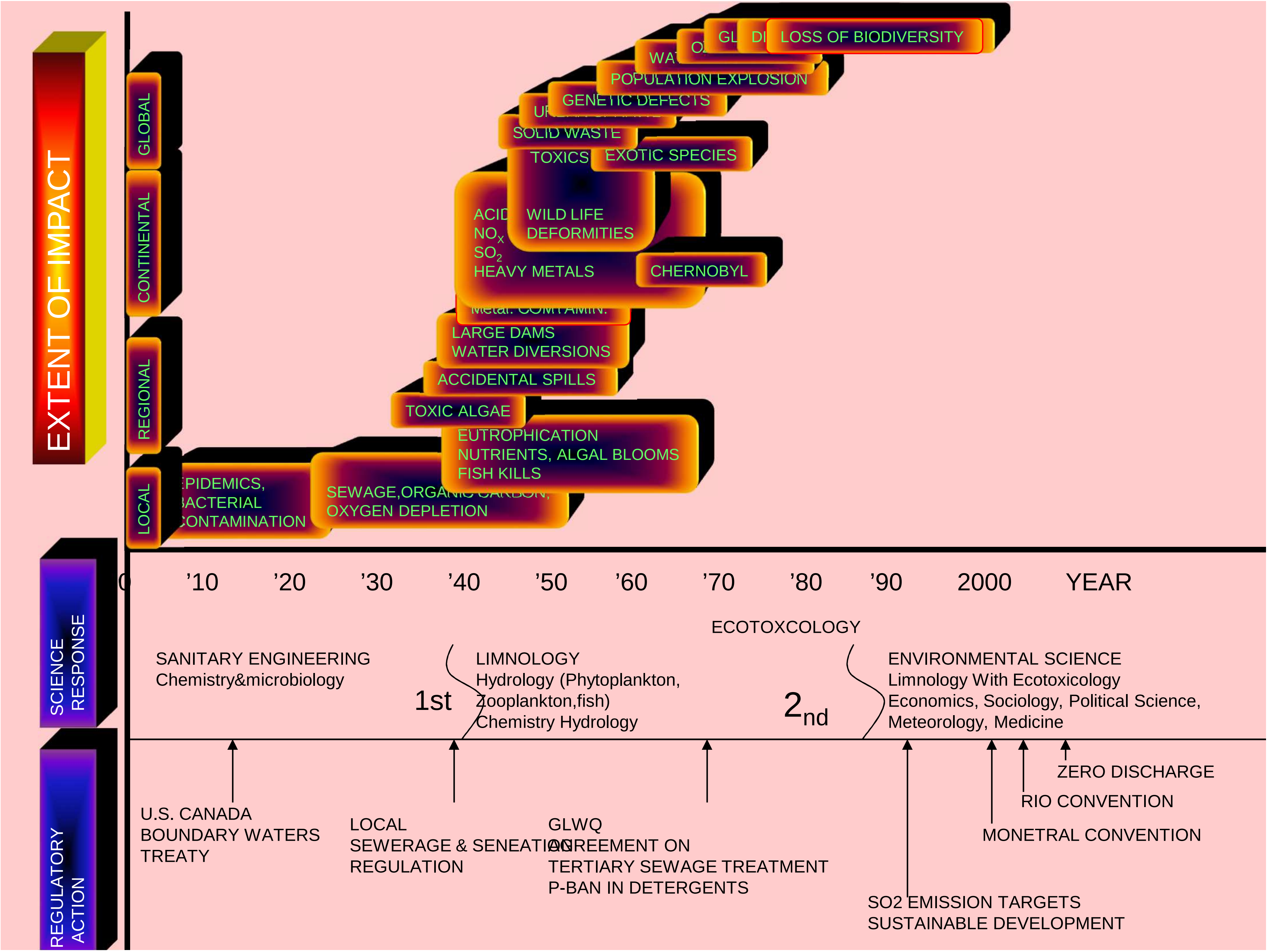
SO_2 emission target
Sustainable development



EXTENT OF IMPACT
GLOBAL
CONTINENTAL
REGIONAL
LOCAL
LOSS OF BIODIVERSITY
POPULATION EXPLOSION
GENETIC DEFECTS
SOLID WASTE
TOXICS
EXOTIC SPECIES
ACID
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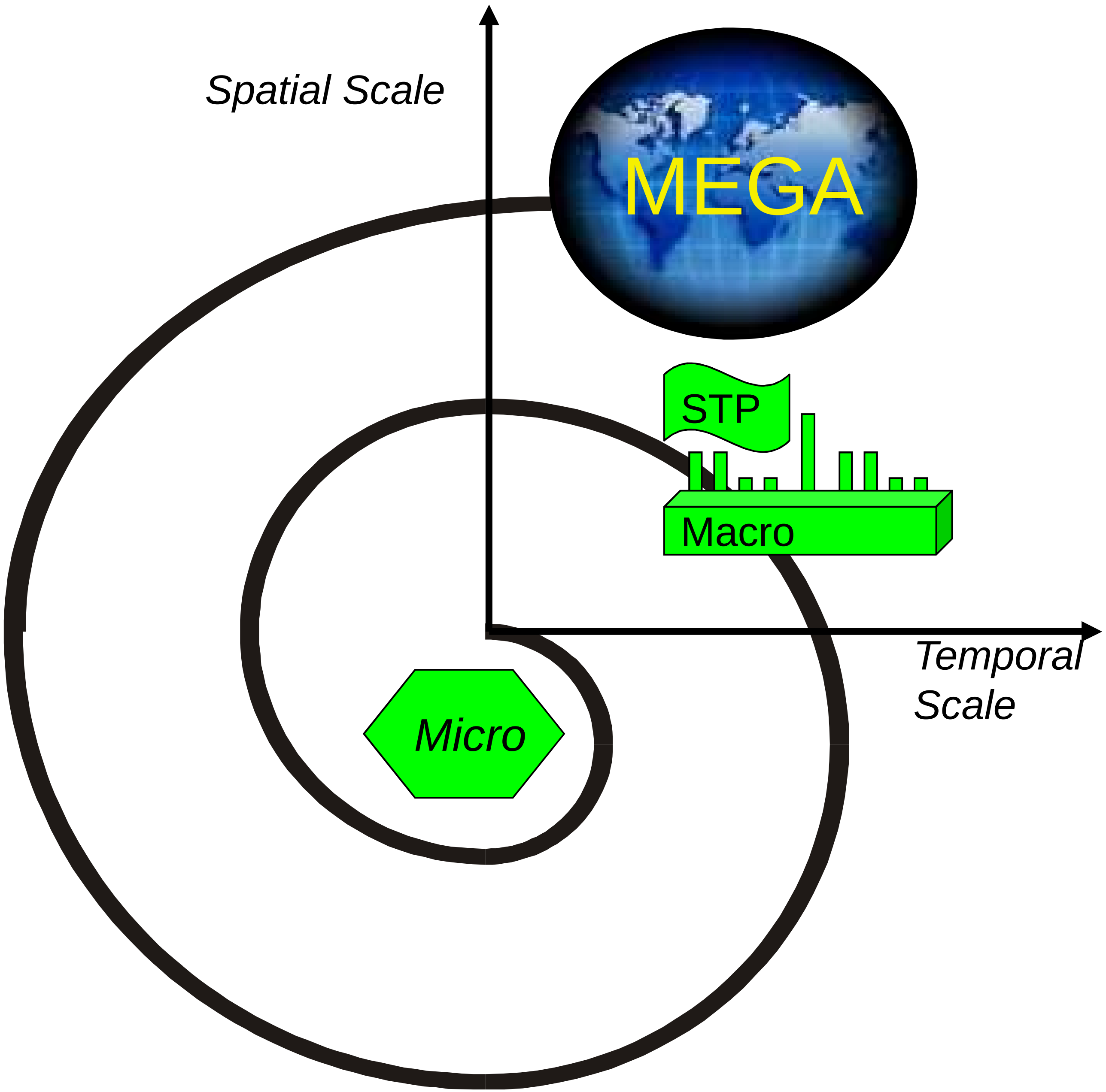
SO2
HEAVY METALS
WILD LIFE
DEFORMITIES
CHERNOBYL
LARGE DAMS
WATER DIVERSIONS
ACCIDENTAL SPILLS
TOXIC ALGAE
EUTROPHICATION
NUTRIENTS, ALGAL BLOOMS
FISH KILLS
SEWAGE,ORGANIC CARBON,
OXYGEN DEPLETION
BACTERIAL
CONTAMINATION
'10
'20
'30
'40
'50
'60
'70
'80
'90
2000
YEAR
SCIENCE RESPONSE
ECOTOXCOLOGY
SANITARY ENGINEERING
Chemistry&microbiology
1st
LIMNOLOGY
Hydrology (Phytoplankton,
Zooplankton,fish)
Chemistry Hydrology
2nd
ENVIRONMENTAL SCIENCE
Limnology With Ecotoxicology
Economics, Sociology, Political Science,
Meteorology, Medicine
REGULATORY ACTION
ZERO DISCHARGE
RIO CONVENTION
U.S. CANADA
BOUNDARY WATERS
TREATY
LOCAL
SEWERAGE & SENEATION
REGULATION
GLWQ
AGREEMENT ON
TERTIARY SEWAGE TREATMENT
P-BAN IN DETERGENTS
MONETRAL CONVENTION
SO2 EMISSION TARGETS
SUSTAINABLE DEVELOPMENT



The environment is in fact a continuum of systems involving similar processes over a remarkable range of temporal and spatial scales.

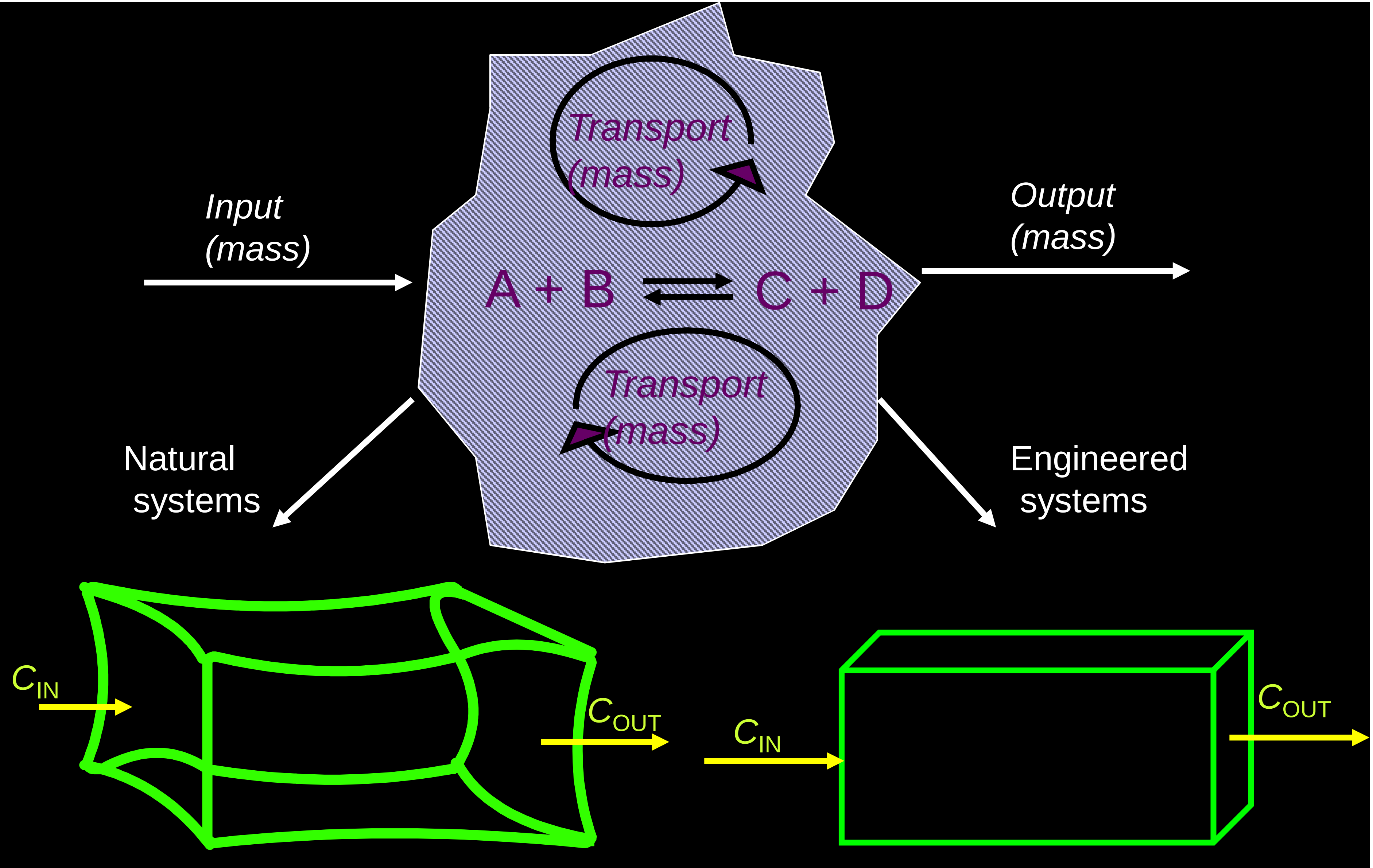
Environmental Systems

- Natural
  - We are concerned with understanding and describing changes
- Engineered
  - We are concerned with the selection of conditions required to effectively accomplish specific changes

Environmental Systems

Natural wetland

Constructed wetland



DESCRIBE

Measure given conditions and describe (model) anticipated changes in constituents

DESIGN

Determine desired changes in constituent(s) and prescribe (model) required conditions

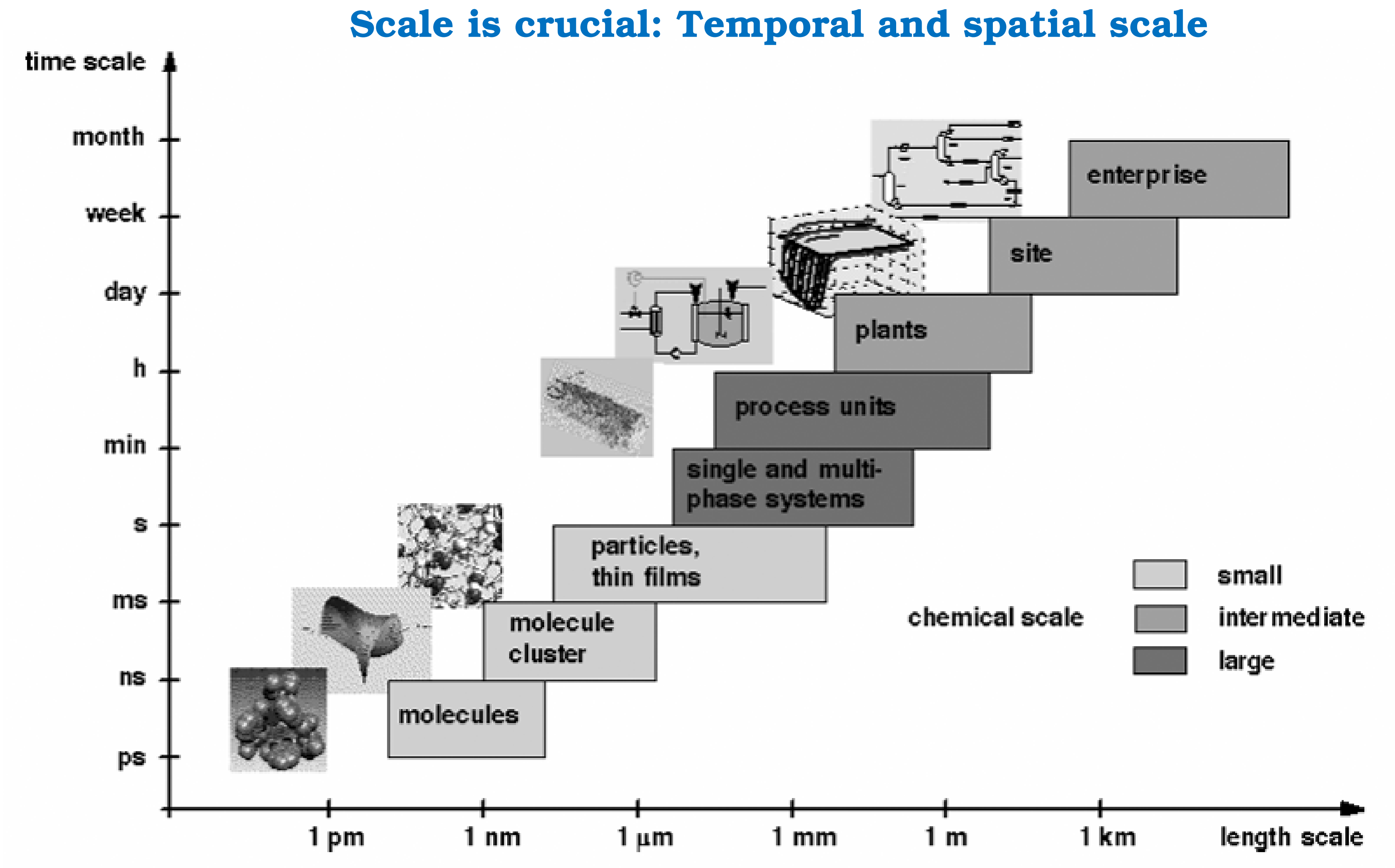
Natural & Engineered Environmental Systems

- While the objectives, information requirements and expected results for natural and engineered systems are usually quite different, the underlying processes and principles of change are essentially the same. Similarly, the methods by which the processes are analyzed and described should be fundamentally the same.
- Successful approaches to system characterizations, process analyses, and quantification of components and constituent changes must in every instance, be based on the same principles and precepts of process dynamics.

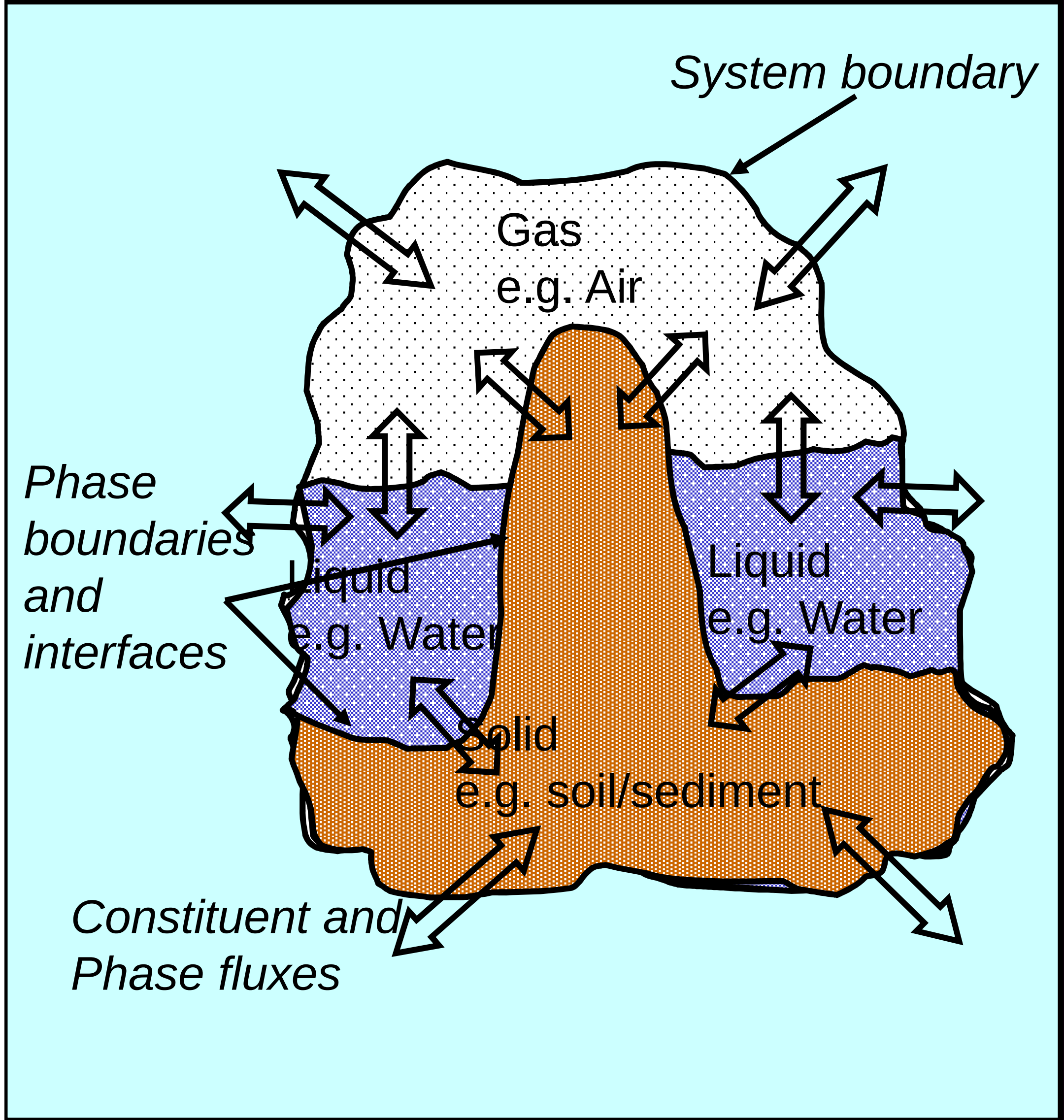
Character and Scale – Natural & Engineered Environmental Systems

- At the most elementary level we distinguish the character of a system on the basis of its scale.
- By character we mean the properties of a system and the nature of changes that occur within it.
- By scale we mean the size (spatial scale) of the system and the time (temporal scale) that together determine the boundaries within and over which the changes of interest occur

Environmental Systems – Scale



Generalized Multiphase System of Gaseous, Liquid and Solid Phases



It is important to note, however, that the composition of each phase depicted in the **Figure** changes as a result of phase and constituent mass reductions and additions that may occur not only by reactions among constituents within the boundaries of phase, but also by movement of mass across its phase boundaries and accumulations or depletions within interfaces at those phase boundaries.

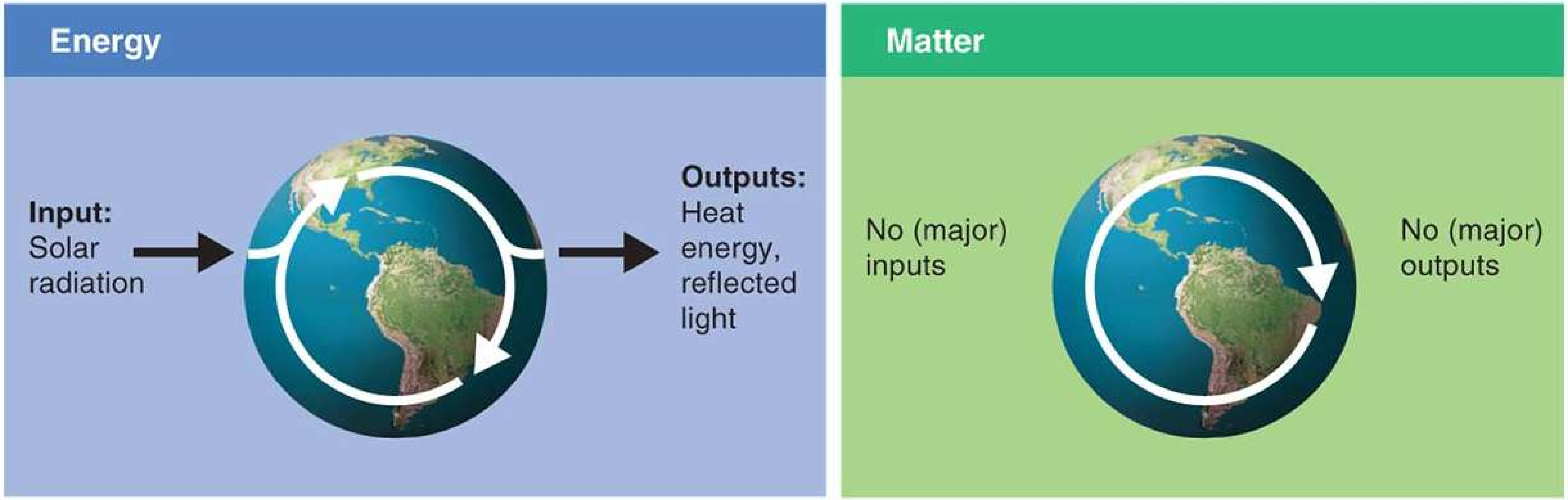
Environmental Systems - Analysis Approach

- All systems are comprised by subsystems; mega-scale systems by macro-scale systems, and macro-scale systems by micro-scale systems. This is why many processes can be influenced at the macroscopic scale by similar microscopic mass transfer phenomenon.
- The most fundamental analysis of any system has its origins ultimately at the molecular level, and must provide that there is a continuity of principles derived from this scale to the full scale of the system.

Environmental System Characterization - System Dynamics

- **Matter and energy flow:** Studying systems allows engineers to think about how energy and matter flow in the environment.
- **Open system:** A system in which exchanges of matter or energy occur across system boundaries.
- **Closed system:** A system in which matter and energy exchanges do not occur across boundaries.
- **Input:** An addition to a system.
- **Output:** A loss from a system.
- **Systems analysis:** An analysis to determine inputs, outputs, and changes in a system under various conditions.
- **Steady state:** A state in which inputs equal outputs, so that the system is not changing over time.

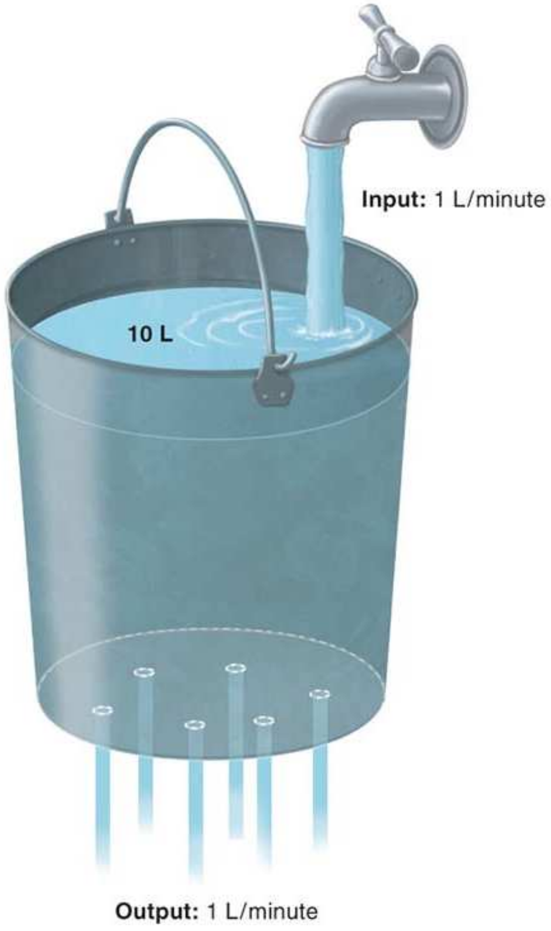
Environmental System Characterization - System Dynamics



(a) Open system **(b)** Closed system

Open and closed systems. (a) Earth is an open system with respect to energy. Solar radiation enters the Earth system, and energy leaves it in the form of heat and reflected light. (b) Earth is essentially a closed system with respect to matter because very little matter enters or leaves Earth's system. The white arrows indicate the cycling of energy and matter.

Environmental System Characterization - System Dynamics

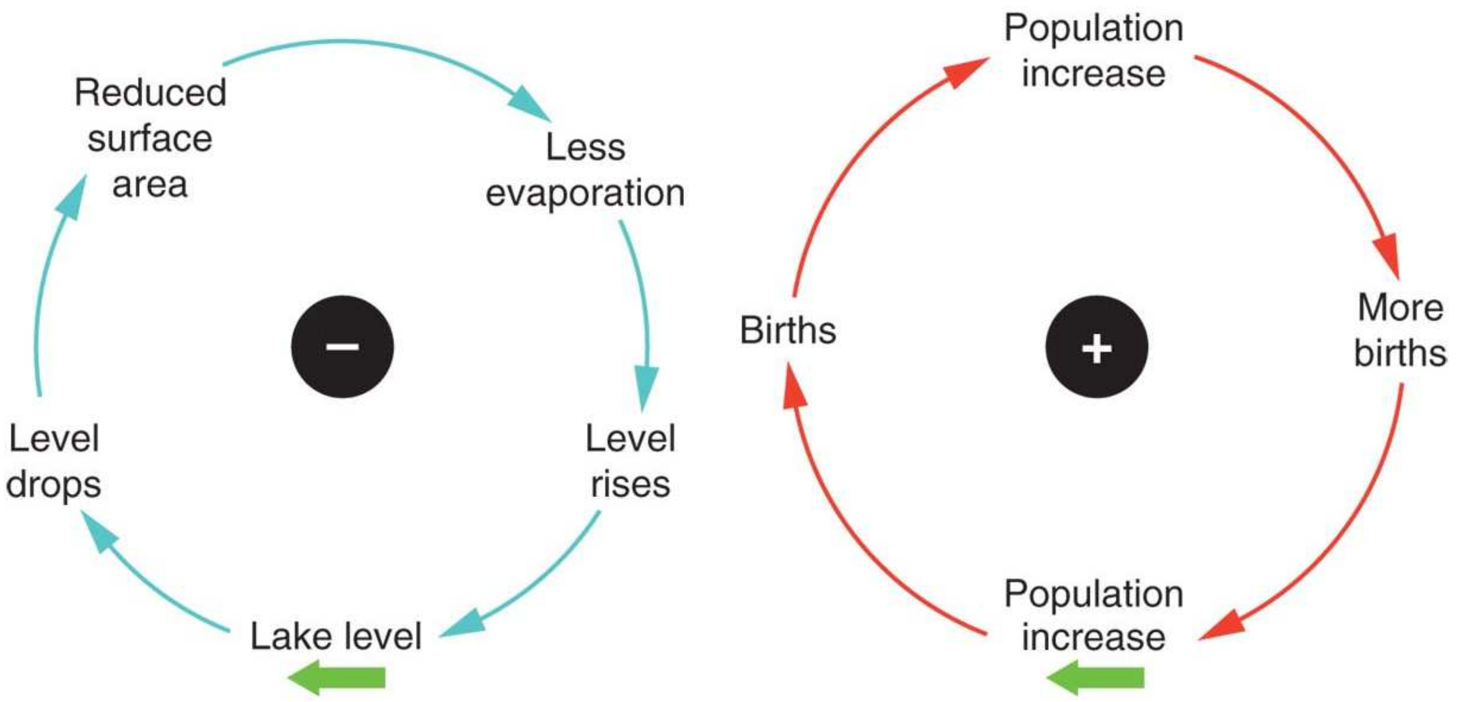


A system in steady state. In this leaky bucket, inputs equal outputs. As a result, there is no change in the total amount of water in the bucket; the system is in steady state.

Environmental System Characterization - System Dynamics

- Feedbacks are found throughout the environment.
- **Negative feedback loop:** A feedback loop in which a system responds to a change by returning to its original state, or by decreasing the rate at which the change is occurring.
- **Positive feedback loop:** A feedback loop in which change in a system is amplified.

Environmental System Characterization - System Dynamics

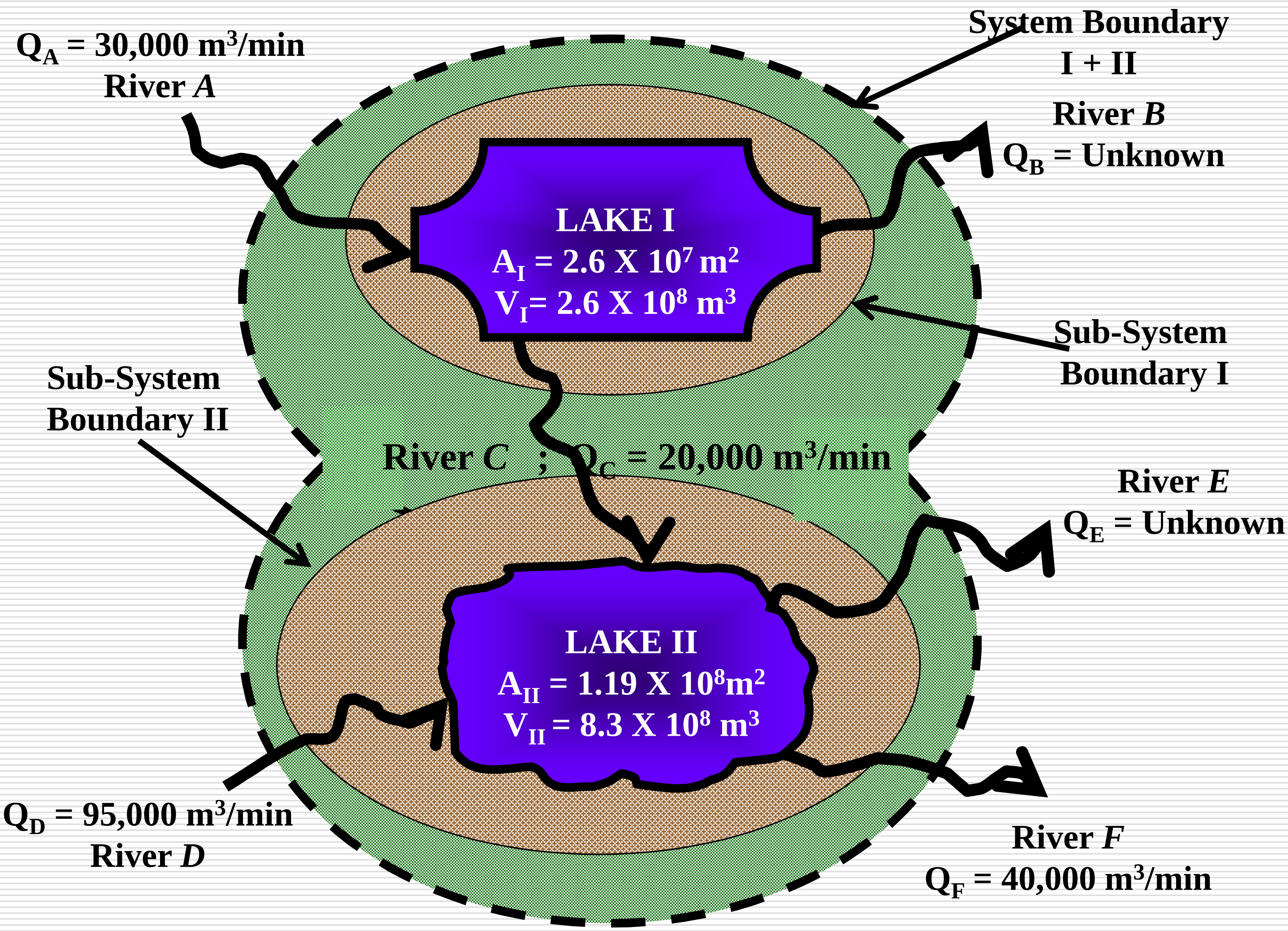


(a) Negative feedback loop **(b)** Positive feedback loop

Negative and positive feedback loops. (a) A negative feedback loop occurs in a lake: A drop in water level reduces the lake surface area and evaporation decreases. The decrease in evaporation causes the lake level to rise again. (b) Population growth is an example of positive feedback. As members of a species reproduce, they create more offspring that will be able to reproduce in turn, creating a cycle that increases the population size. The green arrow indicates the starting point of each feedback loop.

Environmental System Characterization

- We will begin to develop rigorous mass and material balance based approaches to system characterization and analysis
- These approaches can be extended to analysis and design of systems involving increasingly more complex transport and transformation phenomena
- Let us consider a relatively simple environmental system and several sets of different circumstances that lend themselves to intuitive and common sense approach to material balance based "analysis" or "modeling"
- In this we will learn some basic ground rules. Mostly involves *Intuition and Common Sense*



Q_A = 30,000 m^3/min
River *A*
System Boundary
I + II
River *B*
Q_B = Unknown
LAKE I
A_I = 2.6 X 10^7 m^2
V_I= 2.6 X 10^8 m^3
Sub-System
Boundary I
Sub-System
Boundary II
River *C* ; Q_C = 20,000 m^3/min
River *E*
Q_E = Unknown
LAKE II
A_{II} = 1.19 X $10^8$$m^2$
V_{II} = 8.3 X 10^8 m^3
Q_D = 95,000 m^3/min
River *D*
River *F*
Q_F = 40,000 m^3/min

Objective:
Find Q_B and Q_E

- Volumes of lakes are constant
  - i) Define boundary : → system boundary Lake I + Lake II
  - ii) Mass balance of water

$Q_A + Q_D = Q_B + Q_E + Q_F$ ---- 1

steady state condition → temporarily stable condition

Otherwise

$(Q_A + Q_D) - (Q_B + Q_E + Q_F) = d/dt\,(V_I + V_{II})$ ---- 2

  - iii) Redefine boundaries:

Lake I – subsystem → $Q_B = Q_A - Q_C = 10{,}000\ m^3/min$ ---- 3

Lake II – subsystem → $Q_E = Q_C + Q_D - Q_F = 75{,}000\ m^3/min$ ---- 4

What allows us to write above equation is that mass concentration of water in water is constant and equal to its density ρ_ω

$Q_A\,\rho_\omega - Q_B\,\rho_\omega - Q_c\,\rho_\omega = 0$ ---- 5

Assumption → System involved incurred no change in its properties

- Let us complicate by acknowledging that evaporation may be important/significant (r = 0.5 cm/d → $cm^3/cm^2/d$)

- **New sink term**

→ $Q_A \rho_\omega - Q_B \rho_\omega - Q_c \rho_\omega - E_{V,I} \rho_\omega = 0$ ---- 6

(EV,I ρω = 0.5 / 100 X 1440 m/min X 2.6 X 10^7 m^2 = 90 m^3/min)

→ $Q_C \rho_\omega + Q_D \rho_\omega - Q_E \rho_\omega - Q_F \rho_\omega$ - EV,II $\rho_\omega = 0$

(EV,II ρ_ω = 0.5 / 100 X 1440 X 1.19 X 10^8 = 413 m^3/min)

Q_B = 9910 m^3/min

Q_E = 74,600 m^3/min

- Constituent mass balance
- Boundary same as before
- Chloride → no transformation → conservative
- Cl^- is not evaporated
- C_A (Cl^-) = 40 mg/L; C_D (Cl^-) = 60 mg/L

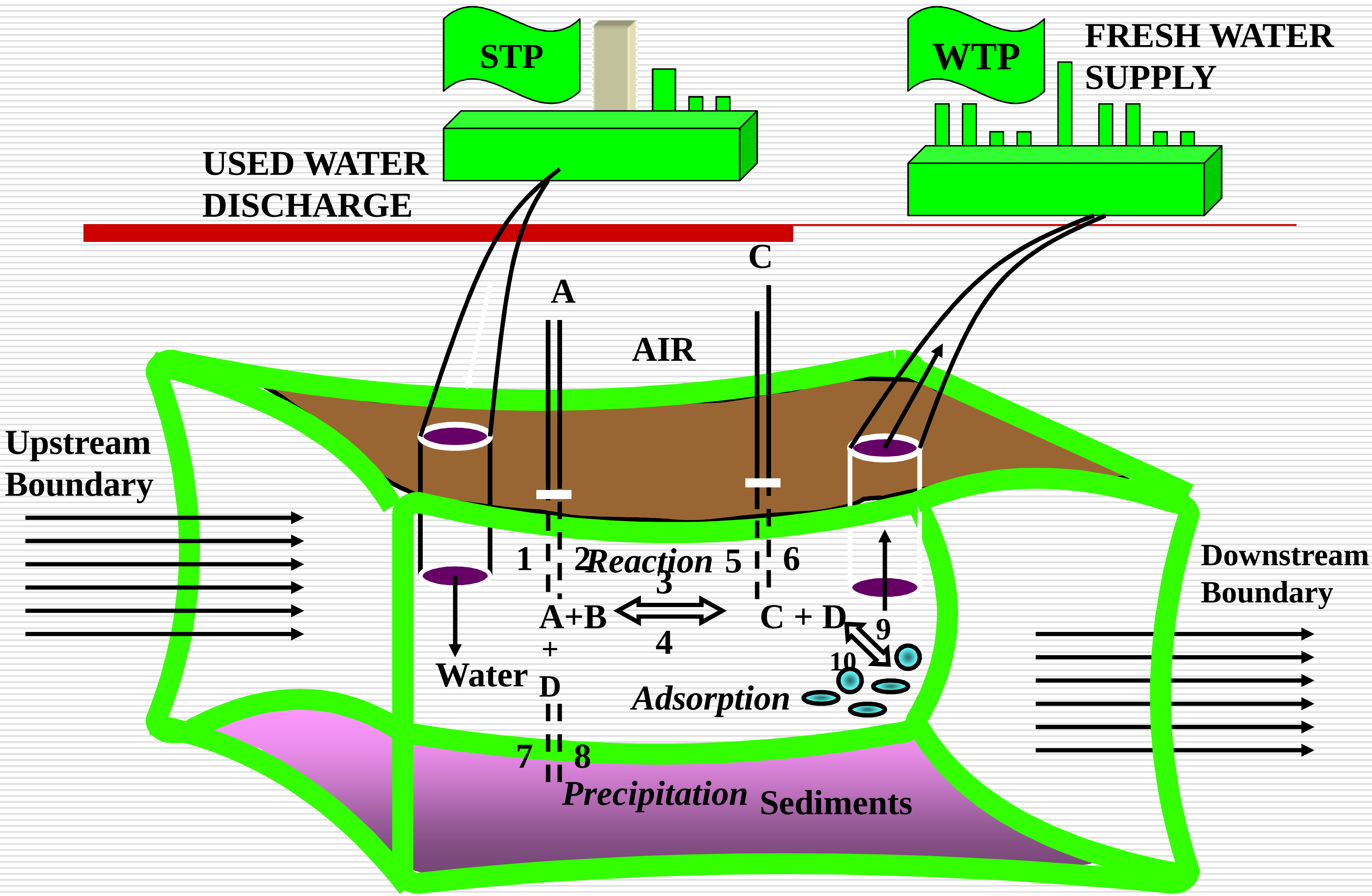
  → Assumption C_B (Cl^-) = C_C (Cl^-) (complete mixing)

$$C_B(Cl) = C_C(Cl) = \frac{30{,}000\,X\,40}{9{,}910 + 20{,}000} = 40.1\,mg/L$$

$$C_E(Cl) = C_F(Cl) = \frac{(20{,}000\,\mathrm{X}\,40.1) + (95{,}000\,\mathrm{X}\,60)}{74{,}587 + 40{,}000} = 56.7\,mg/L$$

In reviewing the constructs of these intuitive "models", note and contemplate these several important points:

1. **Proper selection of boundaries can simplify solutions by reducing the number of unknowns**
2. **A separate and perhaps somewhat different material balance equation must be written for each component of interest**
3. **All transport and transformation processes should be first identified in physical context and then translated into equations**
4. **Any and all assumptions you are making should be identified, stated explicitly and analyzed for merit, and**
5. **Balanced equations should be developed in terms of general variables first, checked for dimensional consistency, and then quantified with numerical parameter values having appropriate units.**



A Natural Environmental Macroscale System