

April 4, 2008

Rubbish, Stink, and Death:
How Engineers Invented
Water Quality Modeling and
How It Might Inform Climate
Change

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OUTLINE

- ☀ The Historical Development of
Civil Engineering***
- ☀ The Roots and History of
Environmental Engineering***
- ☀ The Evolution of Water Quality
Modeling and Management***
- ☀ The Future***
 - ☀ Developing economies***
 - ☀ Climate Change***

HISTORY OF ENGINEERING

MILITARY ENGINEERS



CIVIL(IAN) ENGINEERS

(Battlements, Weaponry)

(Buildings, Roads, Aqueducts)

Scientific Revolution (1600-1700)

Industrial Revolution (1800-1900)

MECHANICAL
**(Steam Engines,
Vehicles)**

CHEMICAL
**(Explosives,
Food, petroleum)**

ELECTRICAL
**(Lighting,
Power)**

CIVIL & ENVIRONMENTAL
(Infrastructure)

Structural
Geotechnical
Construction
Transportation

Environmental
Water resources

What distinguishes CEE from other areas of engineering?

- ☀ We are broad*
- ☀ We plan and manage (big systems)*
- ☀ We deal directly with the government, the public sector, and society*
- ☀ We are outdoors oriented*
- ☀ We own our companies*

*We are the Builders...
of Cities*

THE HISTORY OF ENVIRONMENTAL ENGINEERING

✿ **Where and why did society begin to care about water quality?**

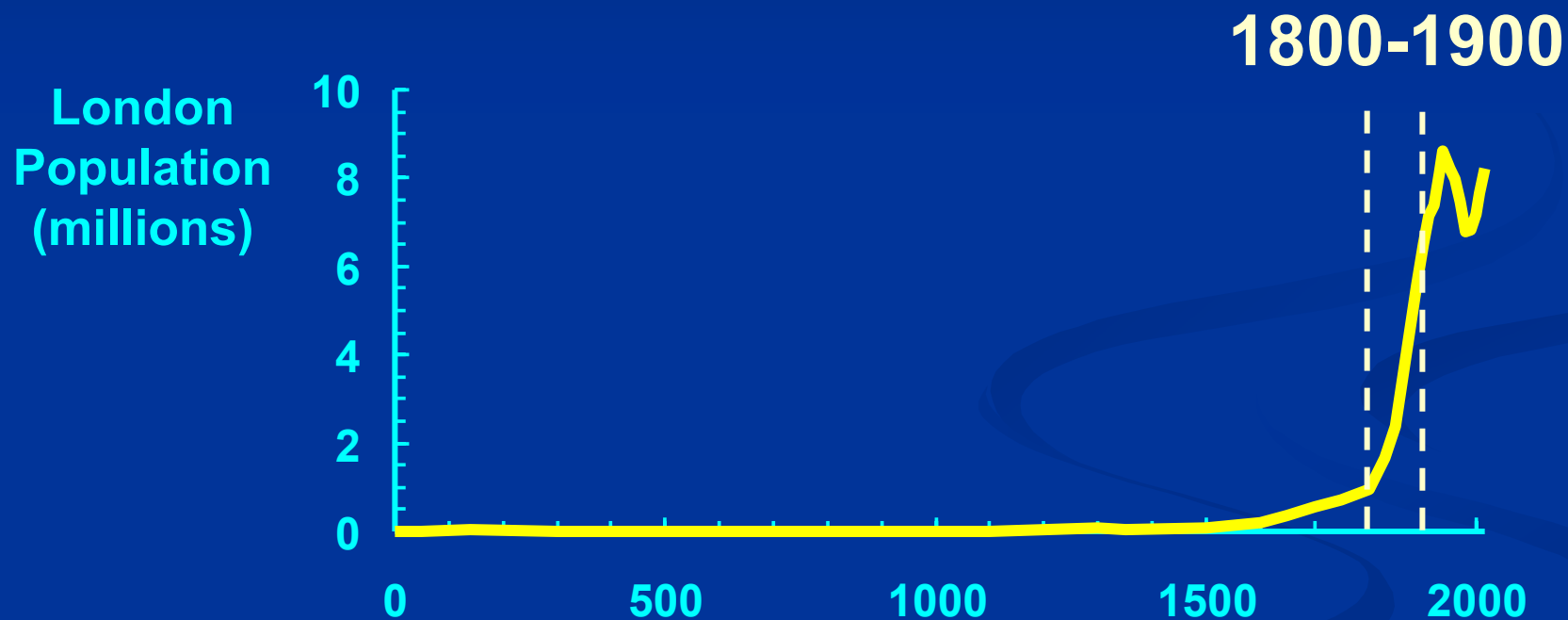
✿ **Jared Diamond (Pulitzer Prize)
“Guns, Germs and Steel”**

✿ **A book about water quality:**

“Rubbish, Stink and Death”

19th Century London

✱ Migration from farms to cities



World's largest city (1831-1925)

Water and Sanitation Infrastructure

- ☀ **Water supply: Mostly wells**

- ☀ **Waste disposal:**

 - ☀ **Mostly cesspits**

 - ☀ **Some sewers**

into the Thames

- ☀ **No waste treatment!!!**

Rubbish ↔ ***Stink*** ↔ ***Death***



Aesthetics

***Ecosystem
health***

***Public
health***

The Great Stink of 1858

- ✱ **Unusually warm summer**
- ✱ **Oxidation of sewage created anaerobic conditions
(no dissolved oxygen)
in the Thames estuary**
- ✱ **Generated hydrogen sulfide gas (rotten egg smell)**



Parliament

***Smell Was So Bad That
Parliament and Law Courts Closed***

Disease

☀ Pre-Enlightenment:

Superstition

☀ 19th Century Cholera Epidemics

☀ Miasma Theory of Disease

Pollution
“smells”



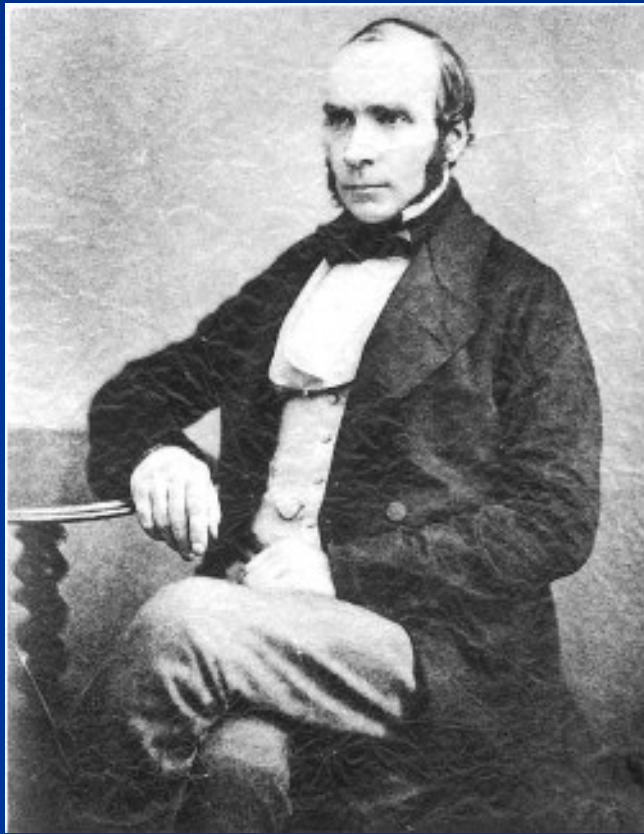
Disease
must be
“airborne”



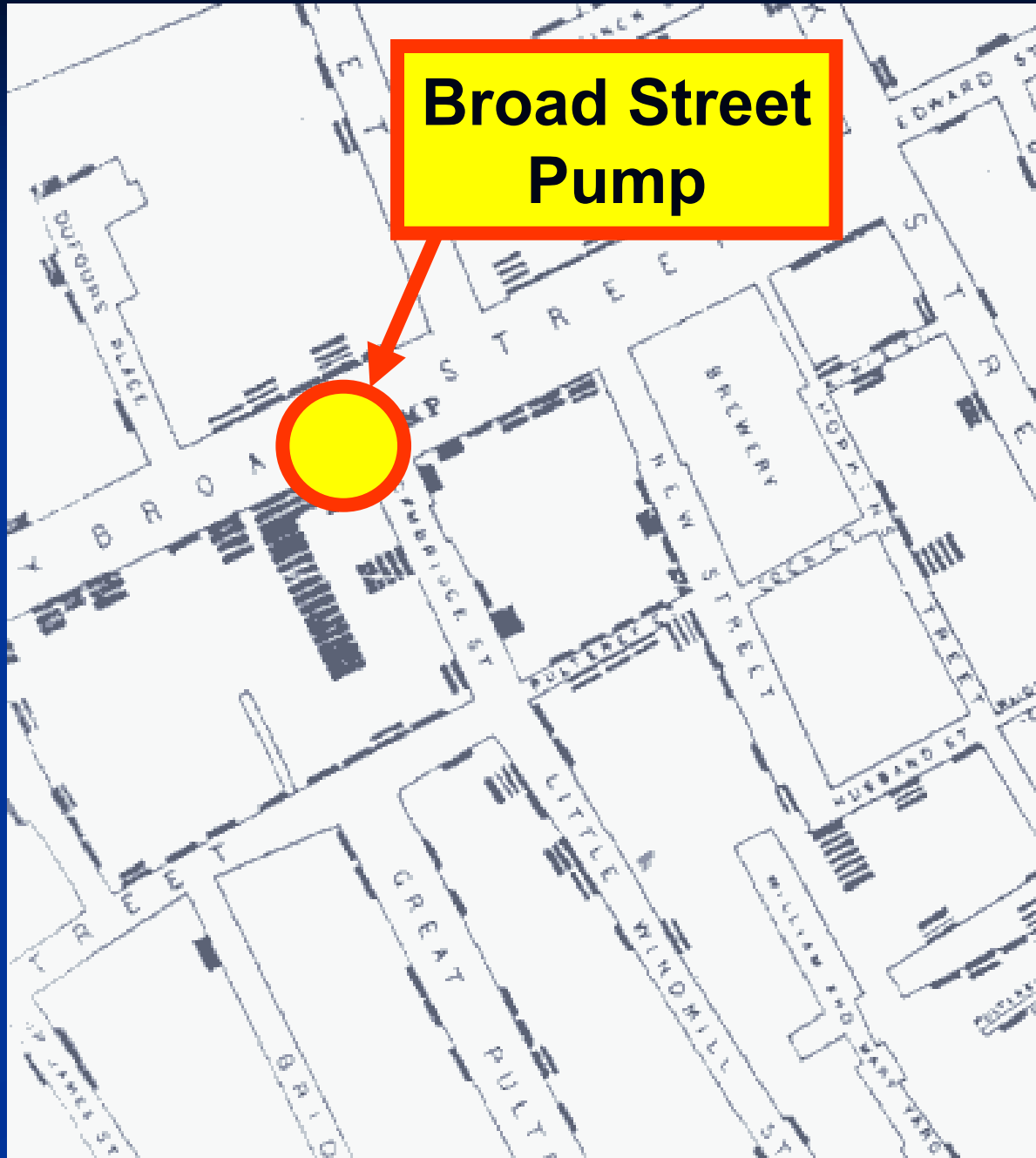
A LONDON BOARD OF HEALTH HUNTING AFTER CASES LIKE CHOLERA.

London Board of Health Hunting Cholera

The Ghost Map



John Snow



King Cholera Mans the Pump



Germ Theory Pasteur



Huge Sewer Construction

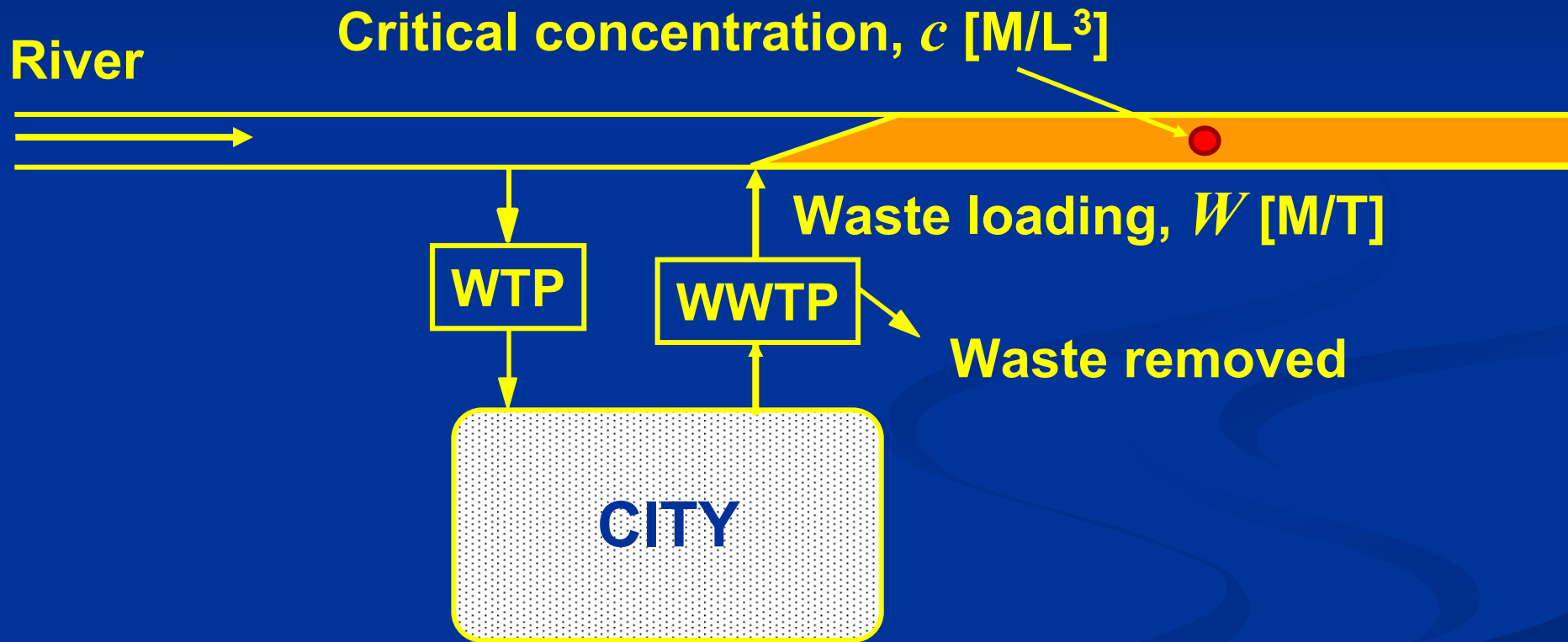


BUILT BY CIVIL ENGINEERS!

Roots of Water Quality Modeling

- ✱ **At first, London relied on tidal flushing**
- ✱ **Then needed additional waste treatment**
- ✱ **How much waste treatment do we need???**

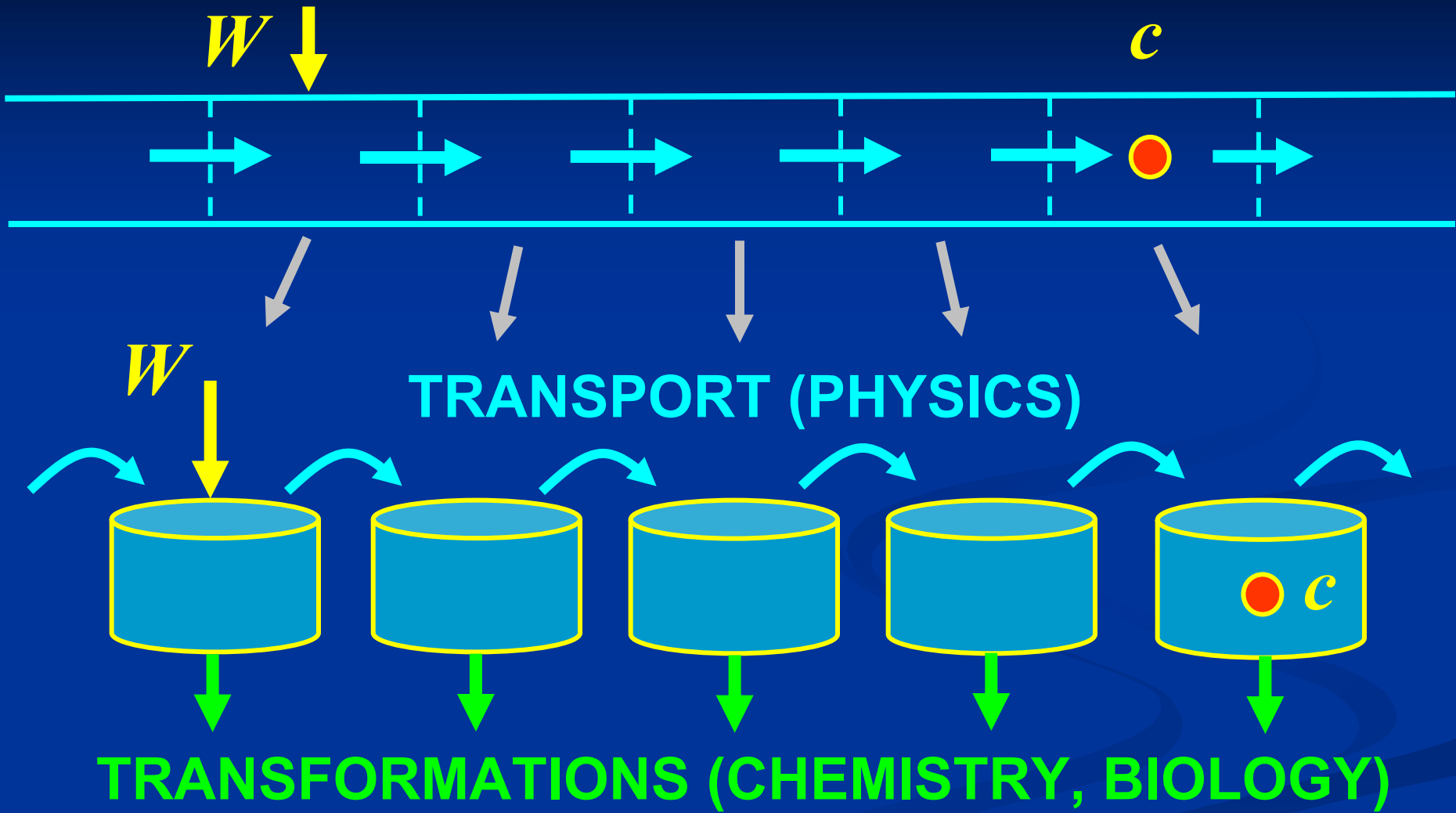
URBAN POINT SOURCE DESIGN PROBLEM (Late 19th & Early 20th Centuries)



WATER-QUALITY MODEL:

$$c = f(W, \text{physics, chemistry, biology})$$

MASS BALANCE

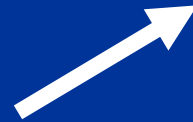


$$c = f(W, \text{physics}, \text{chemistry}, \text{biology})$$

WATER QUALITY MODEL

$$c = f(W, \text{physics, chemistry, biology})$$

$$c = \frac{1}{a} W$$



CONCENTRATION

How polluted
the system is



ASSIMILATION FACTOR

How physics, chemistry and biology convert
the loading rate into concentration



LOADING

The rate of pollutant
discharge

MODELING MODES

SIMULATION MODE:

Given load (W) and assimilation factor (a),

$$c = \frac{1}{a} W$$

ASSIMILATIVE CAPACITY DESIGN MODE:

Given desired concentration (c) and assimilation factor (a),

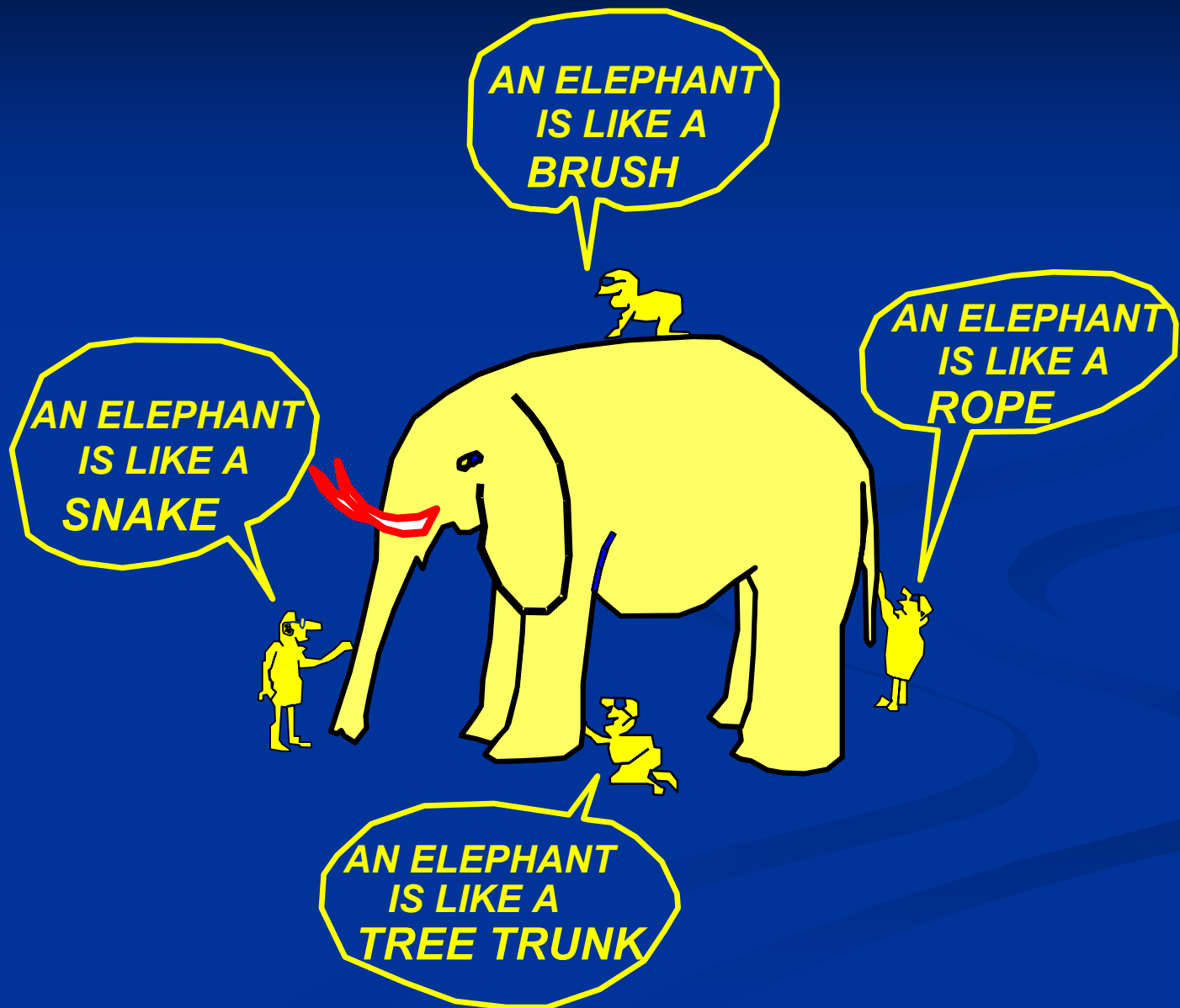
$$W = a c$$

ENVIRONMENTAL MODIFICATION DESIGN MODE:

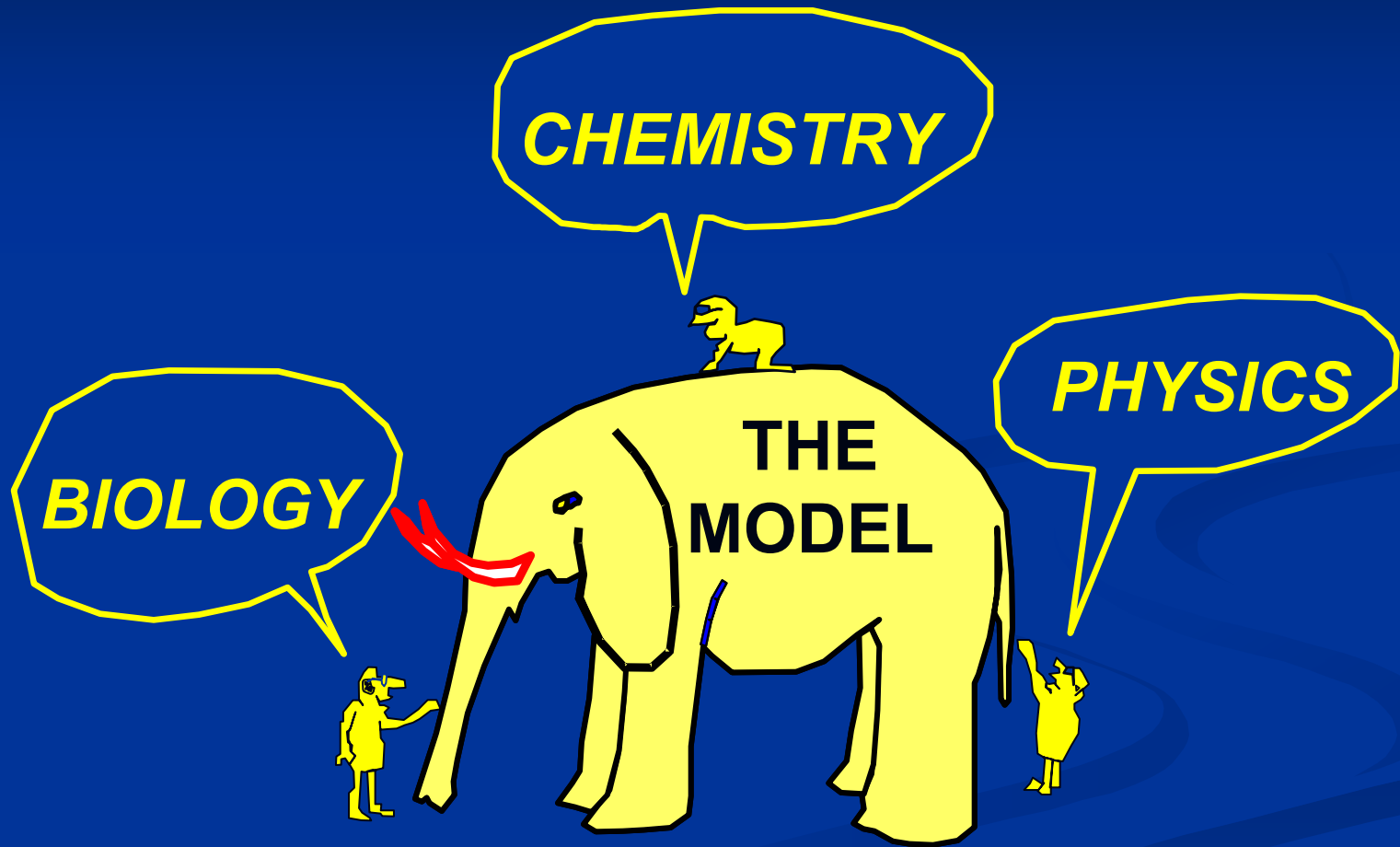
Given desired concentration (c) and given load (W),

$$a = \frac{W}{c}$$

MODELS GIVE YOU THE BIG PICTURE



THE COMPUTER MODEL TIES EVERYTHING TOGETHER



THE PRE-COMPUTER ERA ***(1925-1960)***



Problems: Untreated Sewage Effluent

Pollutants: BOD/Dissolved Oxygen

Systems: Streams/Estuaries (1D)

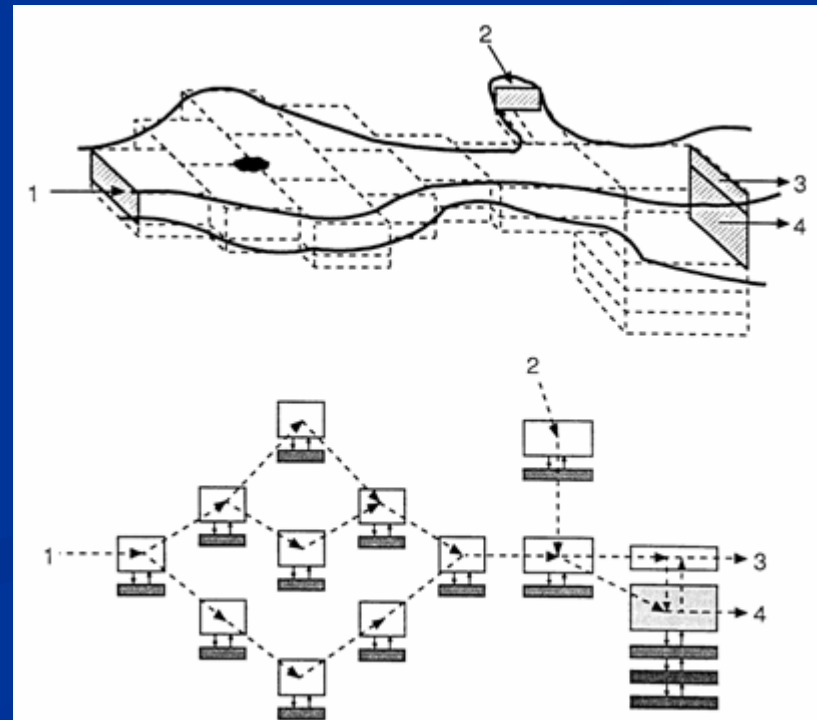
COMPUTERS & PHYSICS (1960-1970)

Problems: Multiple Sewage Effluents

Pollutants: BOD/Dissolved Oxygen

Systems: Streams
Estuaries (1D/2D)

The “systems
approach”



AFTER 1945: KA-BOOM



1950's: THE DREAM



1960's: THE REALITY



EUTROPHICATION

***“Overfertilization
due to excess nutrients”***

BIOLOGY

(1970-1977)

Problems:

Eutrophication

Pollutants:

Nutrients

Systems:

LAKES,
Estuaries
Rivers



TOXICS/CHEMISTRY ***(1977-1995)***

Problems:
Toxics and
Acid Rain

Pollutants:
Organics, Metals, Acid

Systems: Sediments, Ecosystem



TODAY ***(1995-present)***

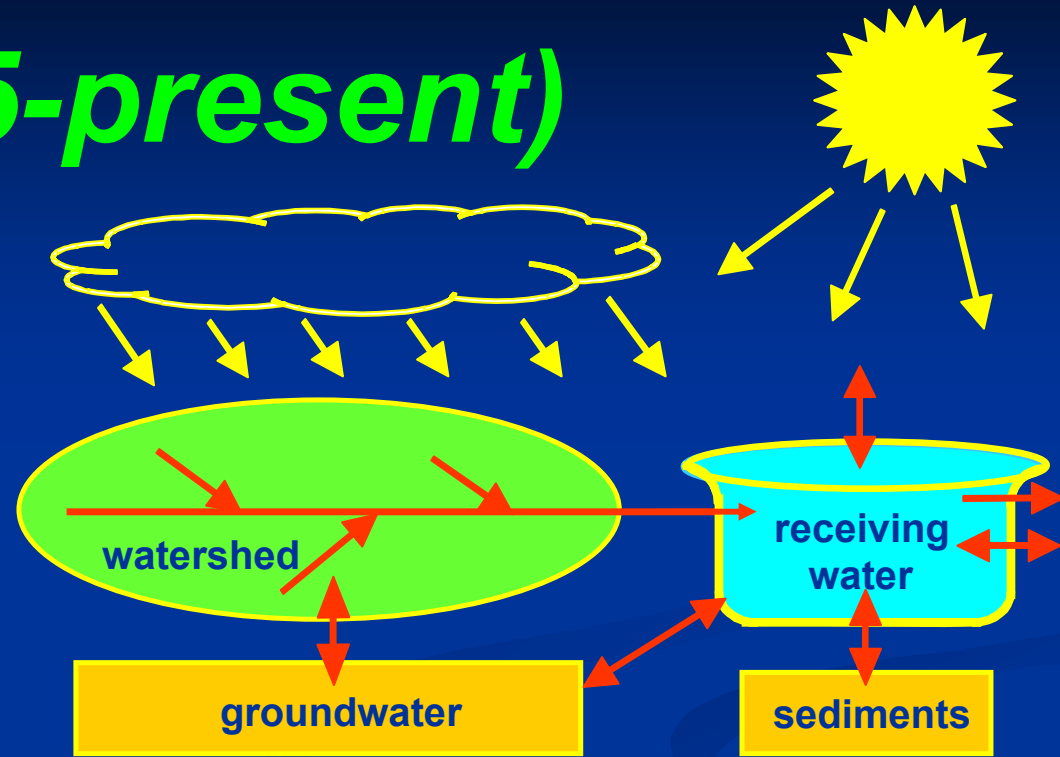
- ☀ Clean Water Act***
- ☀ Computing Advances***
- ☀ Quality of Life***

WATERSHED MANAGEMENT

(1995-present)

Problems:

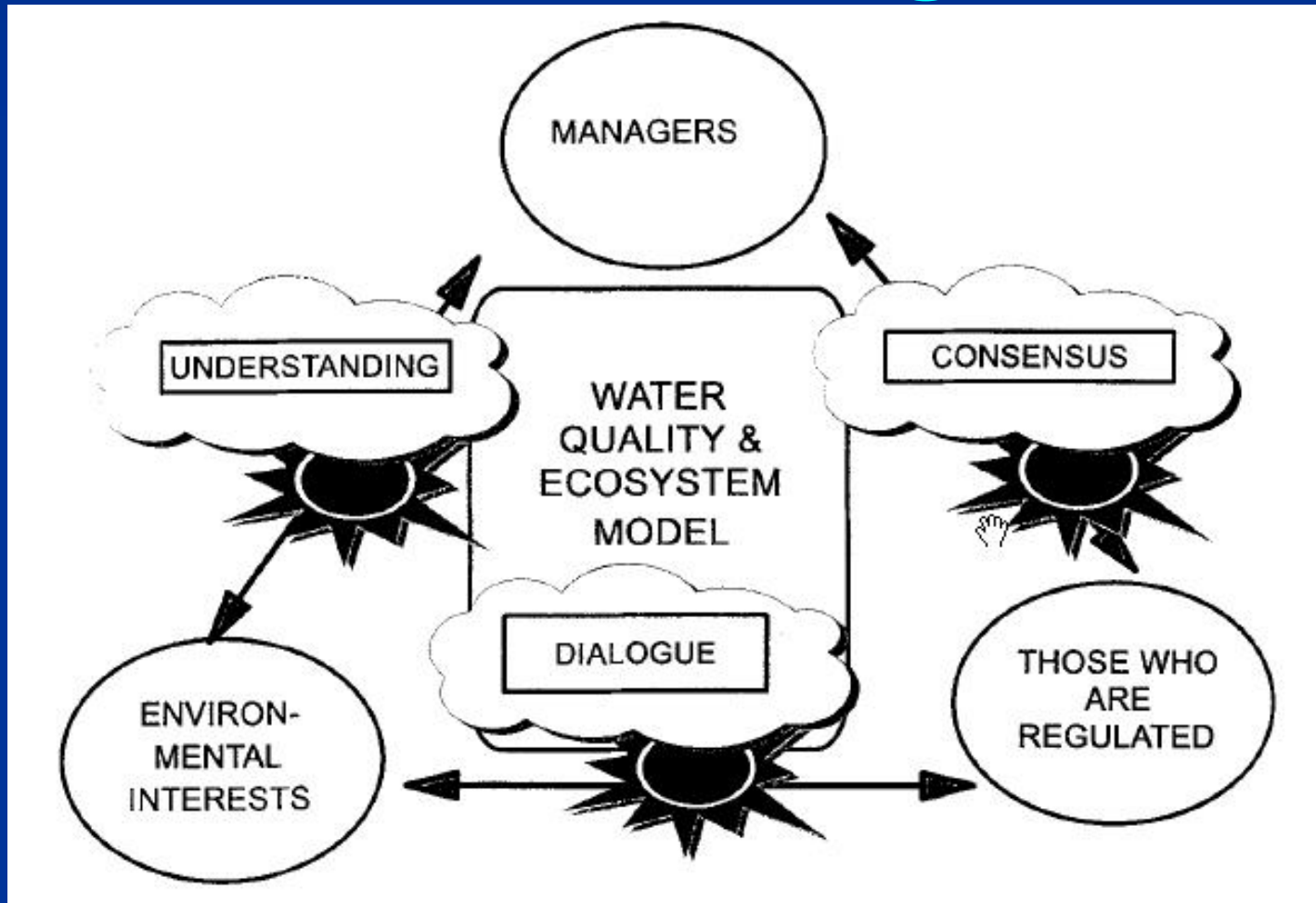
**Temperature,
Eutrophication,
Pathogens,
Toxics**



**Pollutants: Heat, BOD, Nutrients,
Toxics, Bacteria**

**Systems: Watershed, Receiving Water,
Groundwater, Atmosphere**

A Golden Age of Water Quality Management & Modeling



THE FUTURE: DEVELOPING ECONOMIES

- ☀ Water is the oil of the 21st Century***
- ☀ Quantity and Quality***
 - ☀ Clean Water is More Valuable
than Dirty Water***
- A Growing Middle Class***
 - Quality of Life***
 - Tourism***

ECONOMIC EVOLUTION AND ENVIRONMENTAL CONCERNS

**DEVELOPED
ECONOMY**

SUSTAINABILITY

**QUALITY OF LIFE
TOURISM
TRADE**



**PRIMITIVE
ECONOMY**

SURVIVAL

**RUBBISH
SMELLS
DEATH**

CLIMATE CHANGE & WATER QUALITY

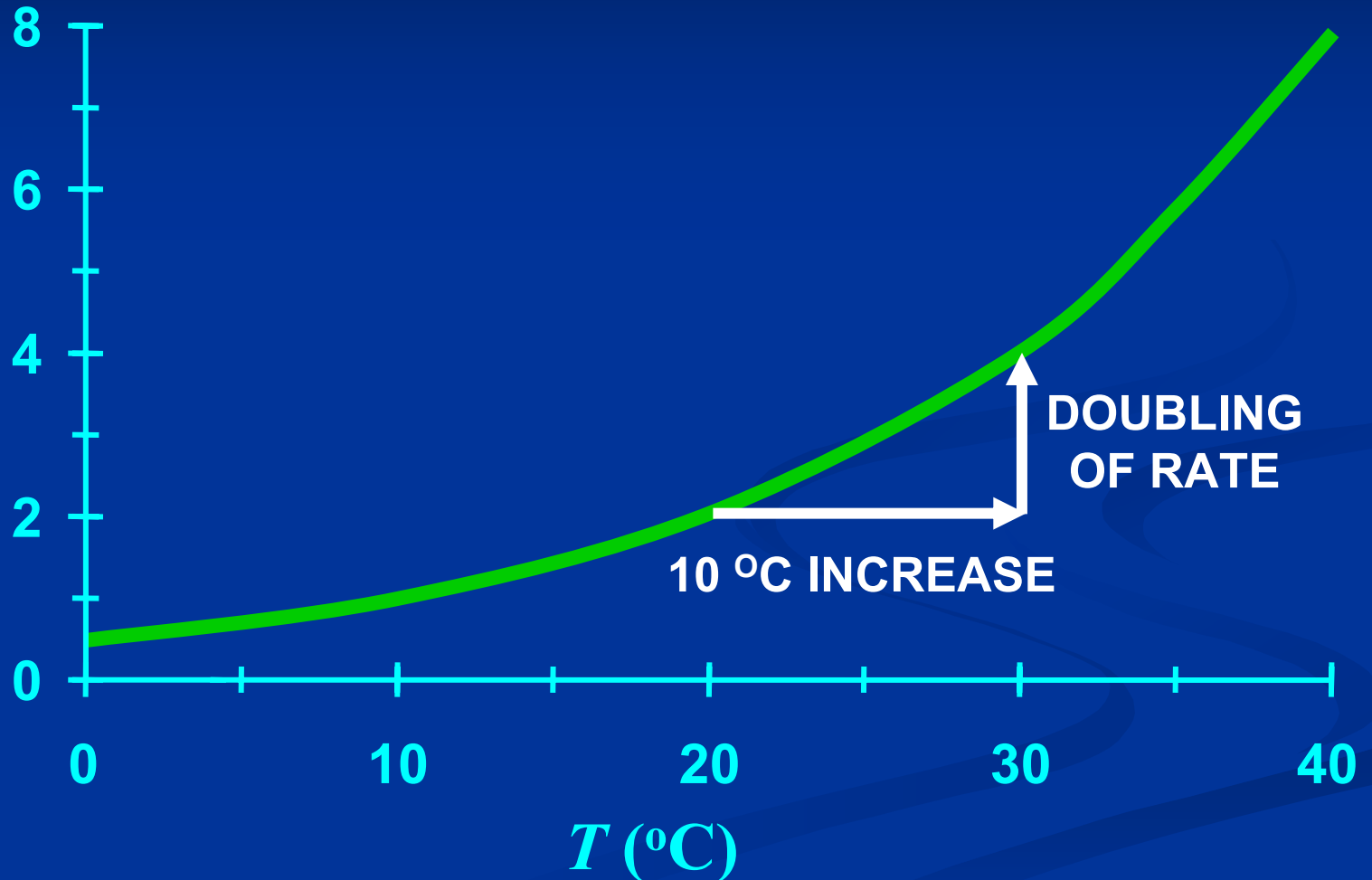
Rubbish, Stink, Death

(and Heat, and Rain and Wind)

- ☀ Biological Impacts***
- ☀ Chemical Impacts***
- ☀ Physical Impacts***
- ☀ How Models Can Help***

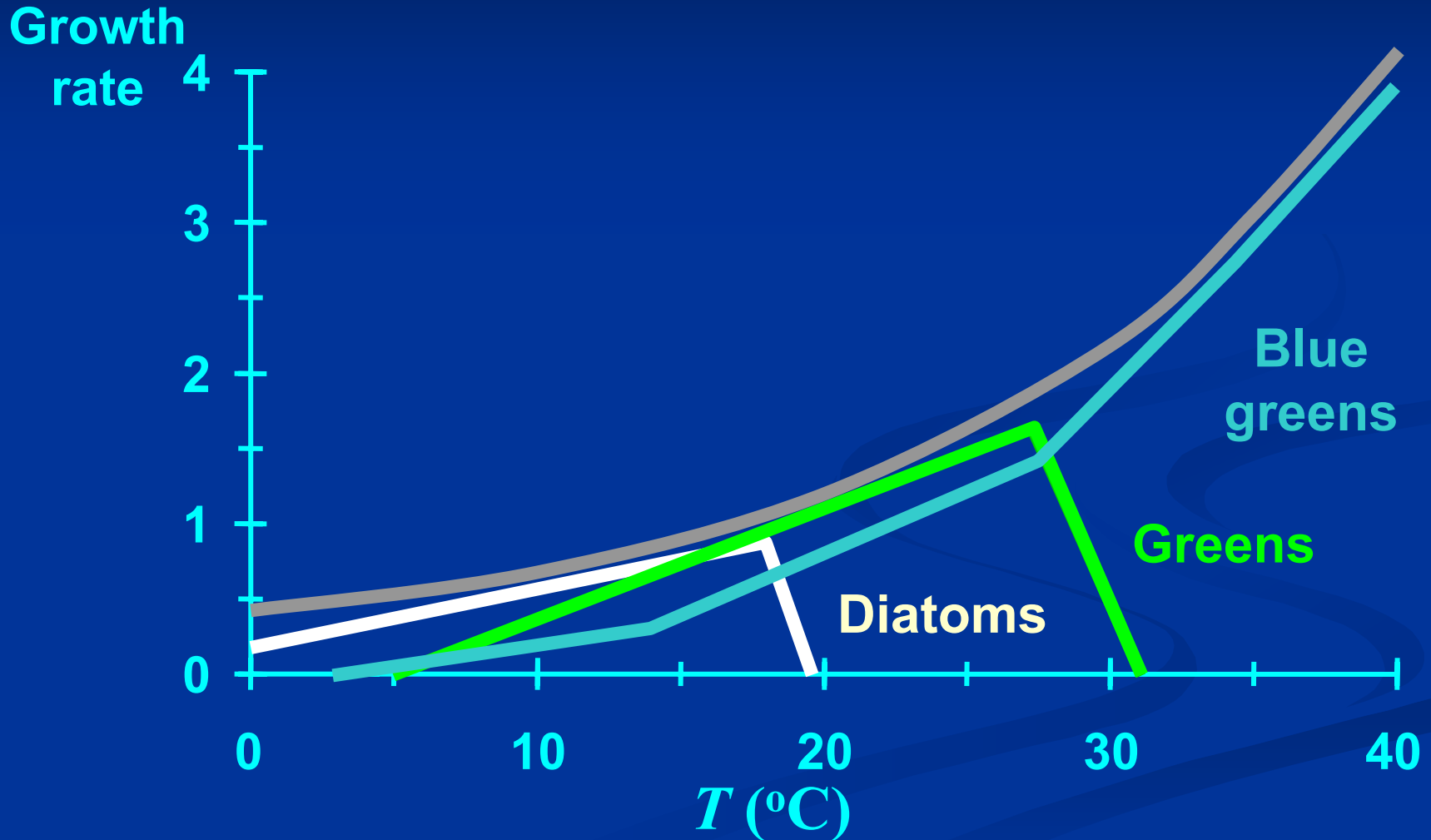
TEMPERATURE IMPACT ON MICROORGANISMS

Growth
rate



THIS IS WHY WE REFRIGERATE

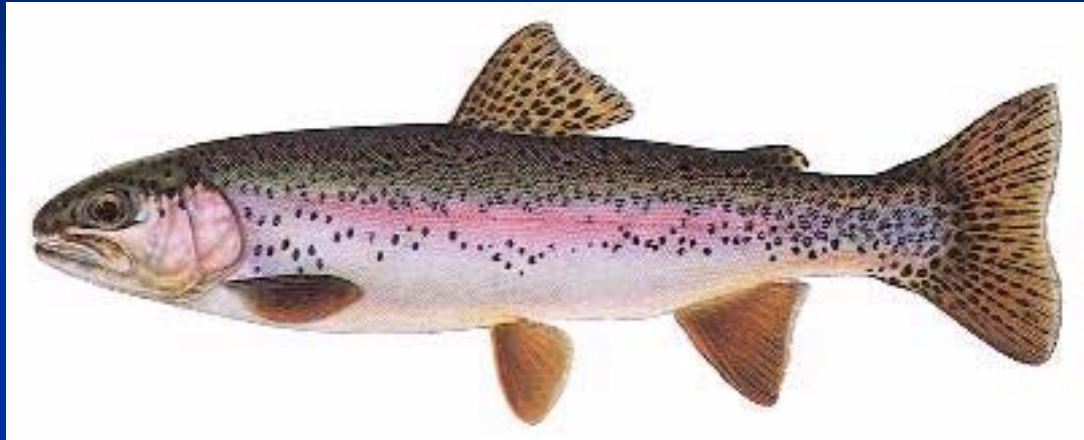
TEMPERATURE IMPACT ON BIOLOGY SPECIES TOLERANCES



BLUEGREEN ALGAE AKA CYANOBACTERIA

-  ***Form unsightly scums***
-  ***Cannot be eaten***
-  ***Some are highly toxic***

HIGHER ORGANISMS: THE SALMONID IN THE COAL MINE

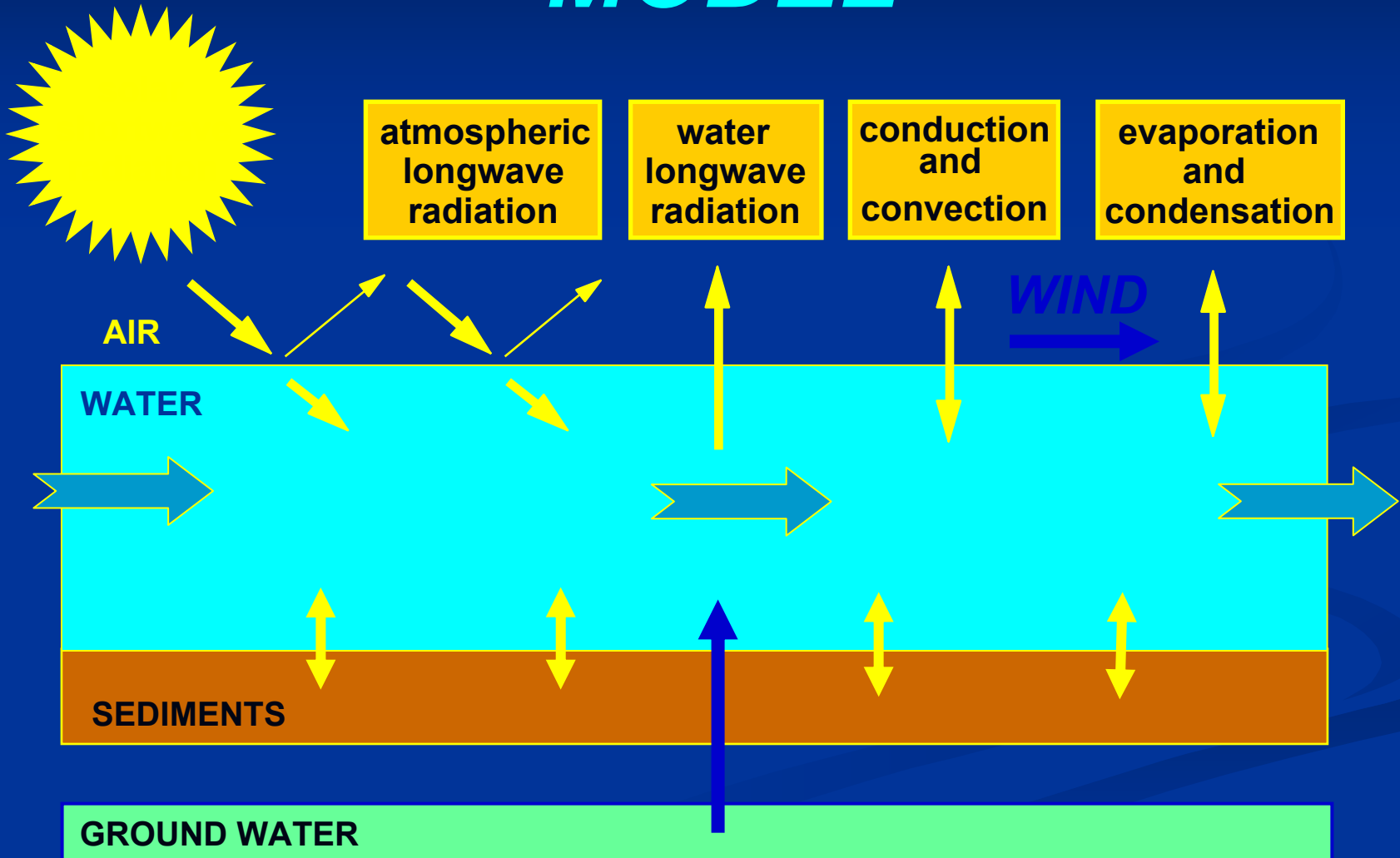


- Highly sensitive to temperature
- And chemistry and biology
- Some are endangered
- Recreational value (S. Africa)
- Commercial value (aquaculture)

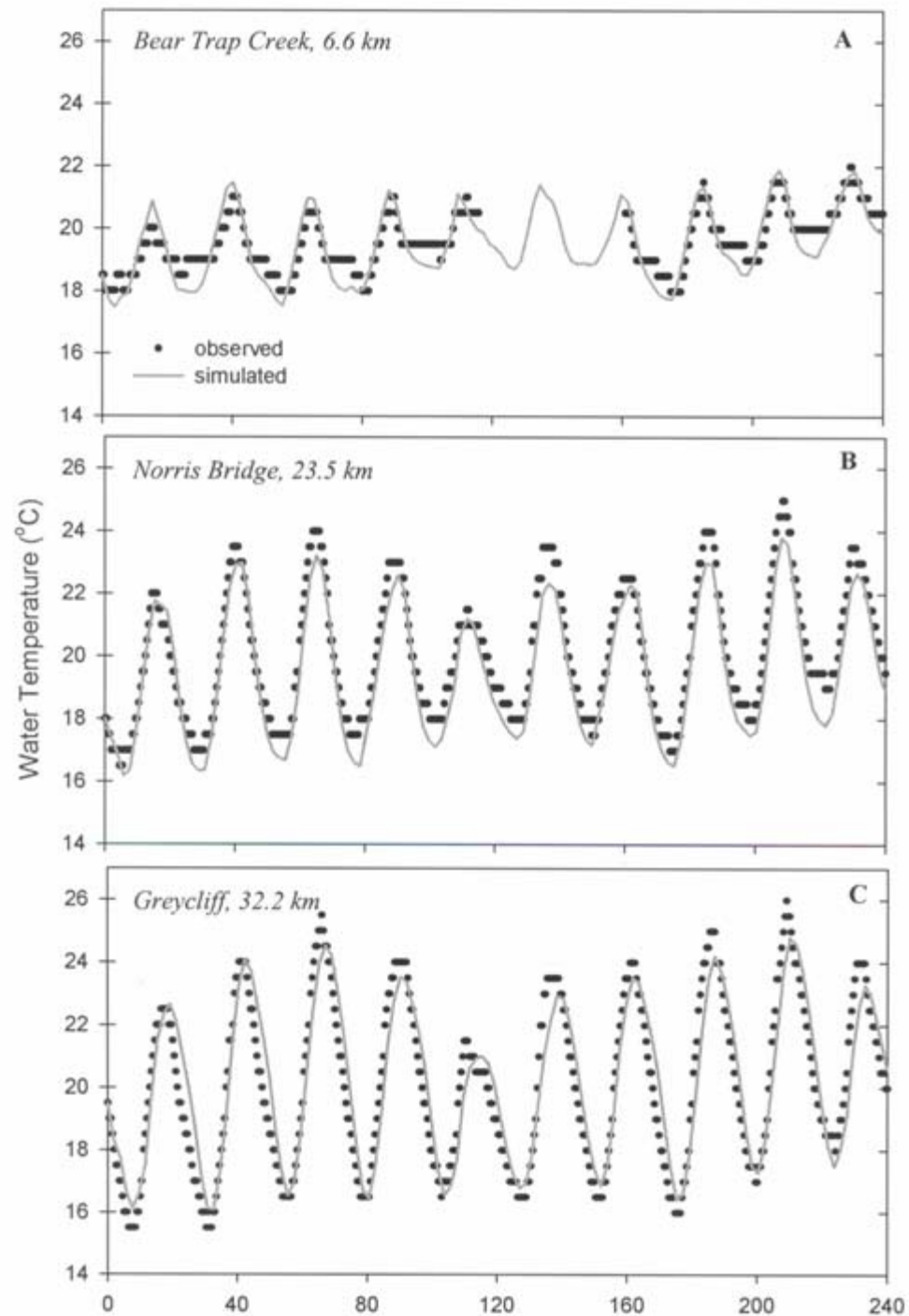
LOWER MADISON RIVER MONTANA



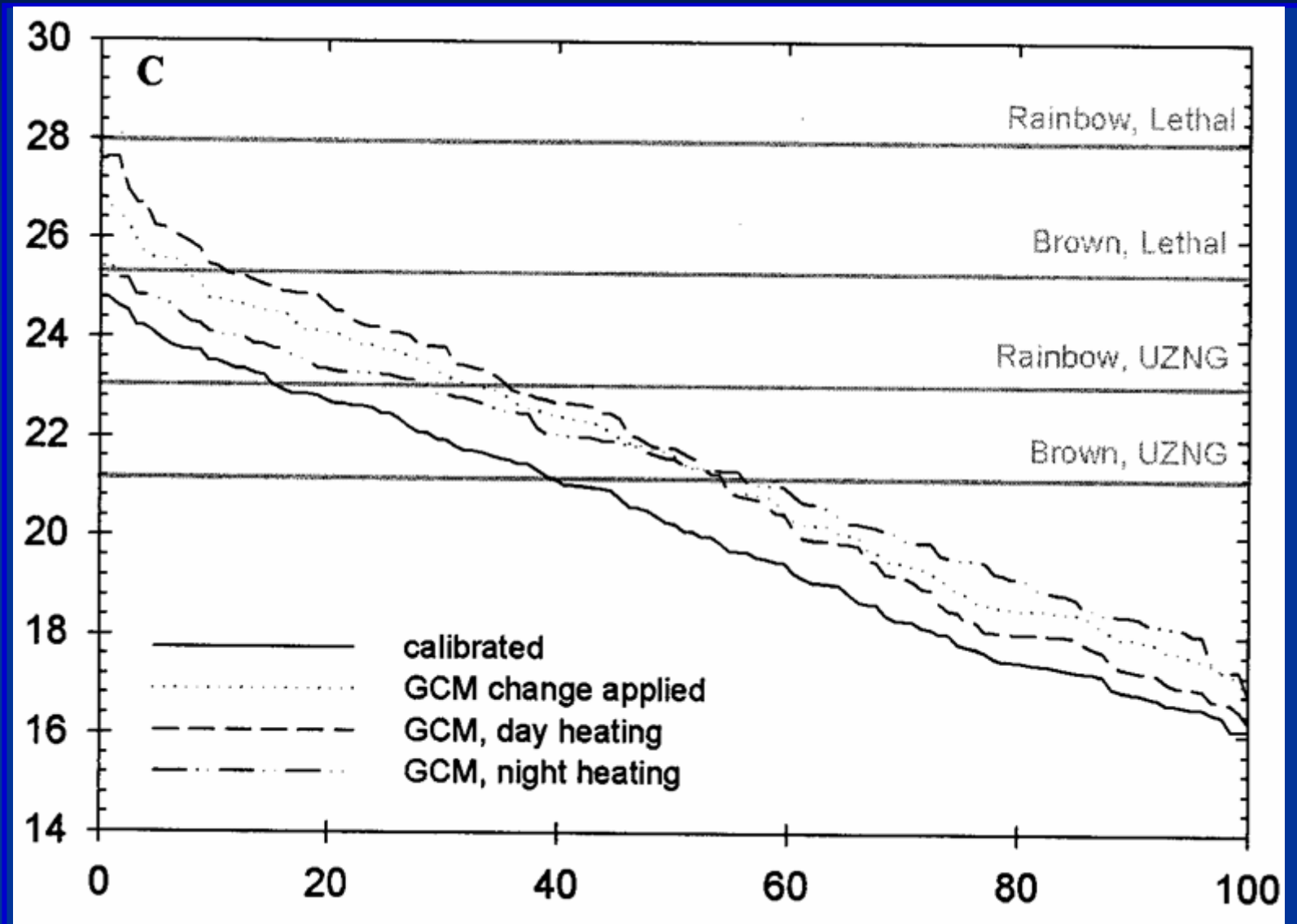
RIVER TEMPERATURE MODEL



Simulation Results

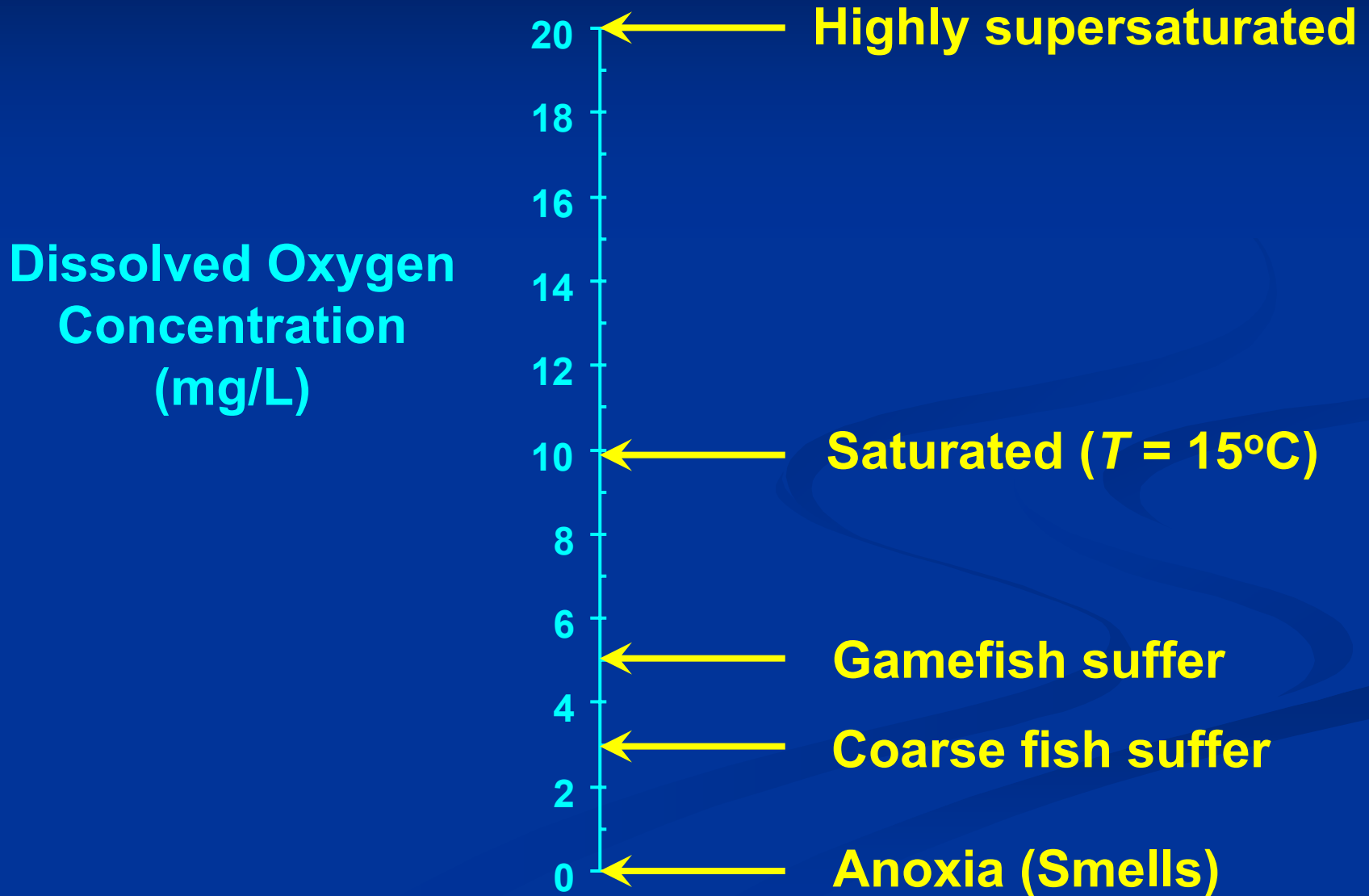


Impact of Climate Change*

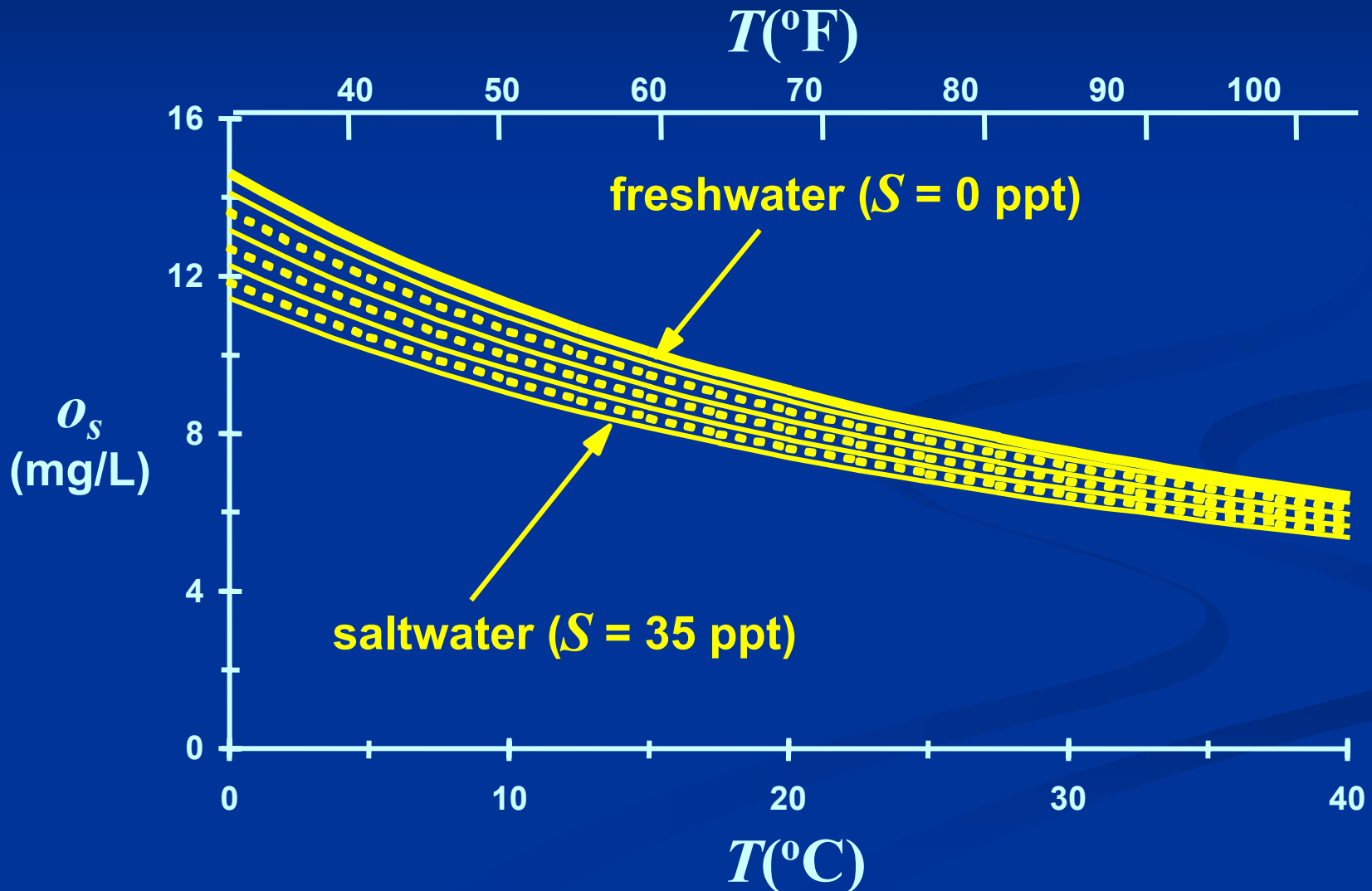


CHEMICAL IMPACTS

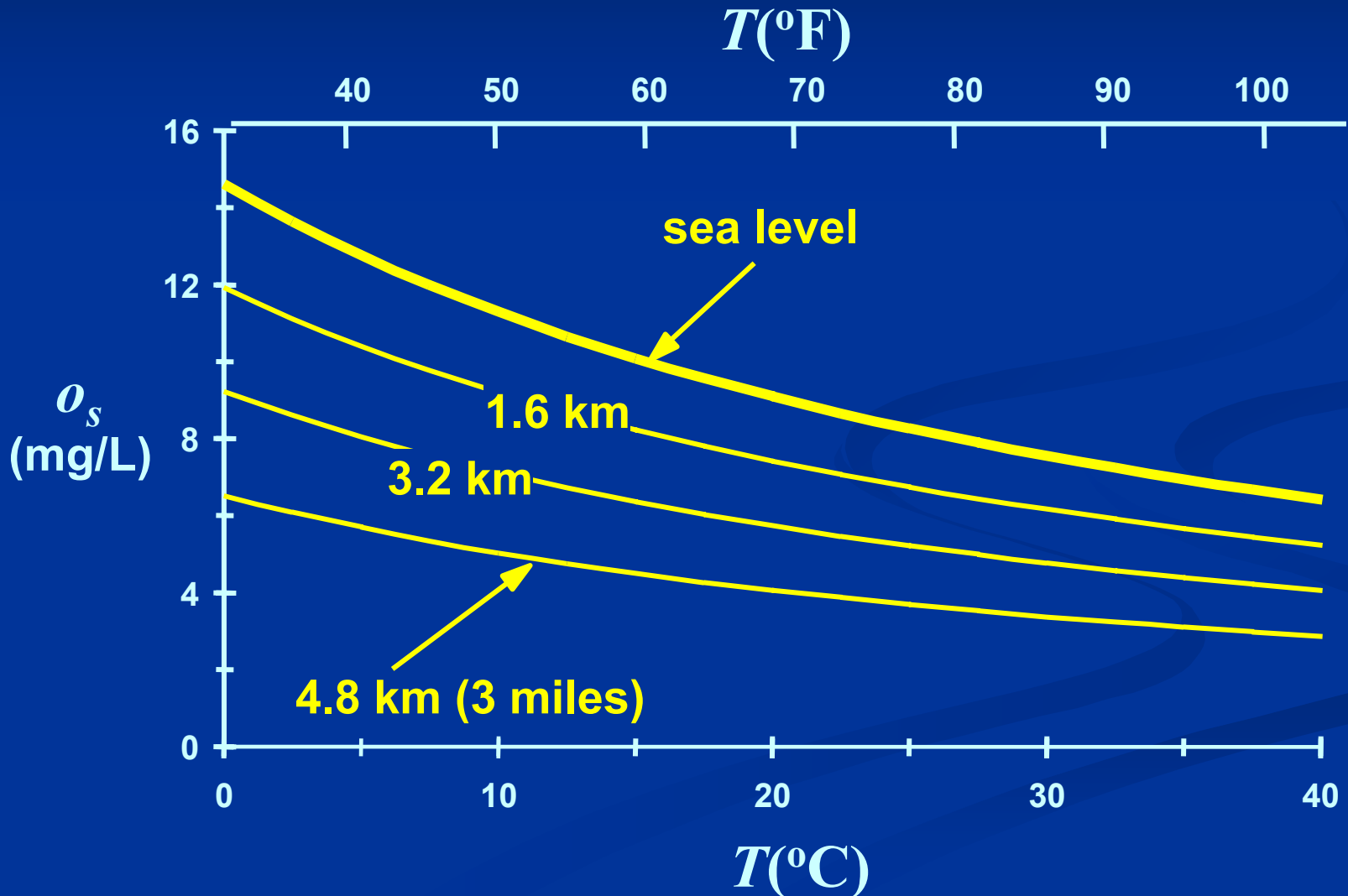
Oxygen: The Breath of Life



OXYGEN SATURATION IN WATER TEMPERATURE EFFECT



OXYGEN SATURATION IN WATER PRESSURE (ELEVATION) EFFECT



PHYSICS

It's not just temperature

☀ *High flows*

☀ *More severe storms*

☀ *Low flows*

☀ *Less snow pack*

☀ *Longer dry periods*

HIGH FLOWS

- ✱ ***Higher erosion***
- ✱ ***Loss of topsoil***
 - ✱ ***Suspended solids***
 - ✱ ***Nutrients***
- ✱ ***Siltation and habitat***
- ✱ ***Light extinction***

HIGH FLOWS

- ✱ ***Urban settings***
- ✱ ***Stormwater overflow***
- ✱ ***Shanty towns***
- ✱ ***Disease transmission***

LOW FLOWS

- ☀ ***Less snowpack***
- ☀ ***Less baseflow***
- ☀ ***Warmer groundwater***
- ☀ ***Shallower rivers***
- ☀ ***Less dilution***

LOW FLOWS

- ☀ *Estuaries*
- ☀ *Saltwater intrusion*
- ☀ *Organism shifts*

HOW CAN MODELS HELP

- ☀ ***Holistic perspective***
- ☀ ***What ifs***
- ☀ ***Consciousness raising***
- ☀ ***Management***
- ☀ ***Planning***
- ☀ ***Consensus building***

Who nabbed Al Capone AKA Scarface



Accountants!!!

If you want to catch a crook

Follow the money!

If you want to save the planet

***Follow the physics, the
chemistry and the biology***

THE END