Updated: 9 September 2019

Print version

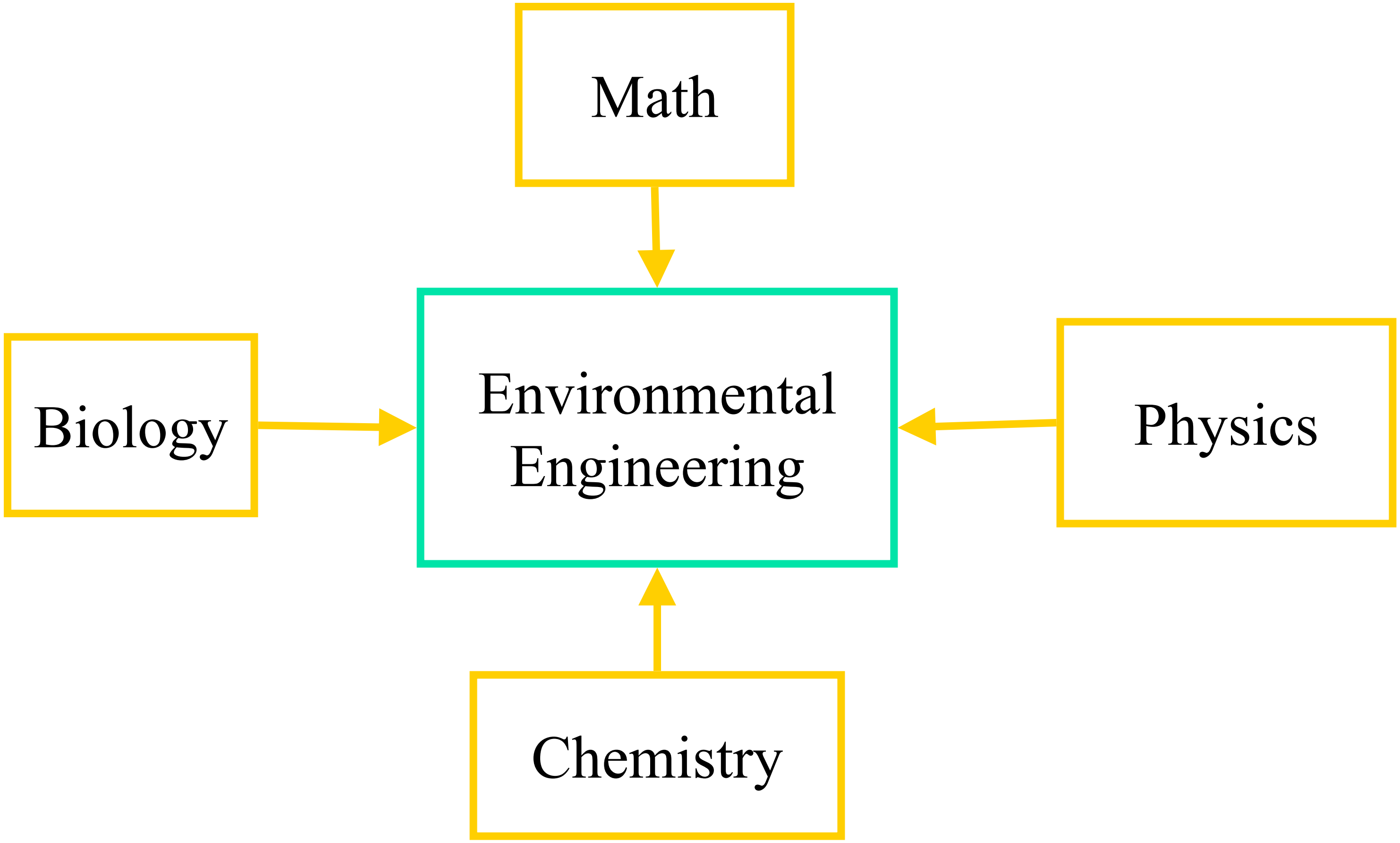
CEE 370 Environmental Engineering Principles

Lecture #3

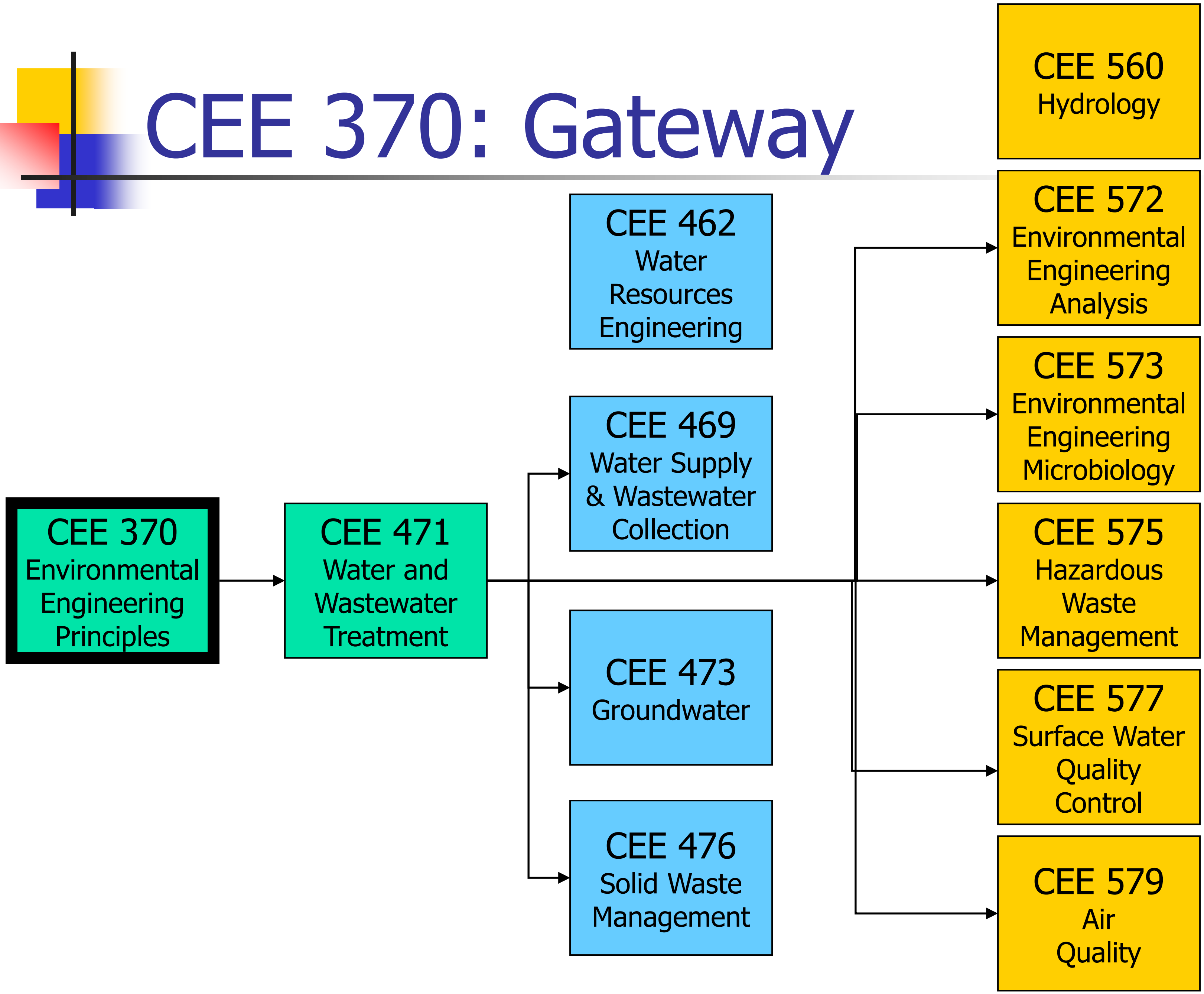
Environmental Chemistry I: Units of Concentration

Reading: M&Z, Chapt 2

Environmental Engineering: Interdisciplinary



CEE 370: Gateway



What Environmental Engineers Do

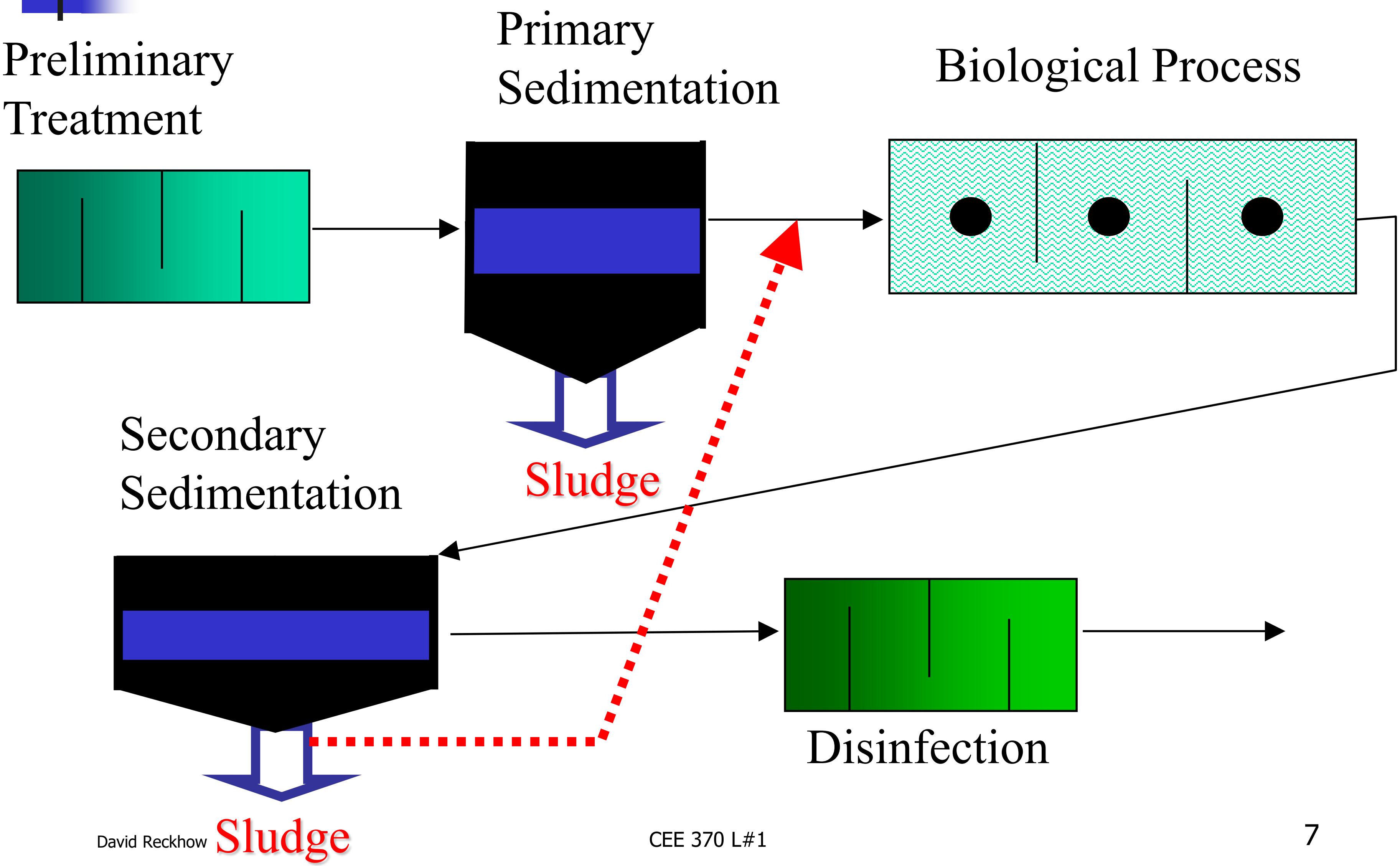
- Three examples
  - Water: Wastewater treatment
  - Air: Acid Rain
  - Solids: VOCs in Soils

Secondary Clarifiers

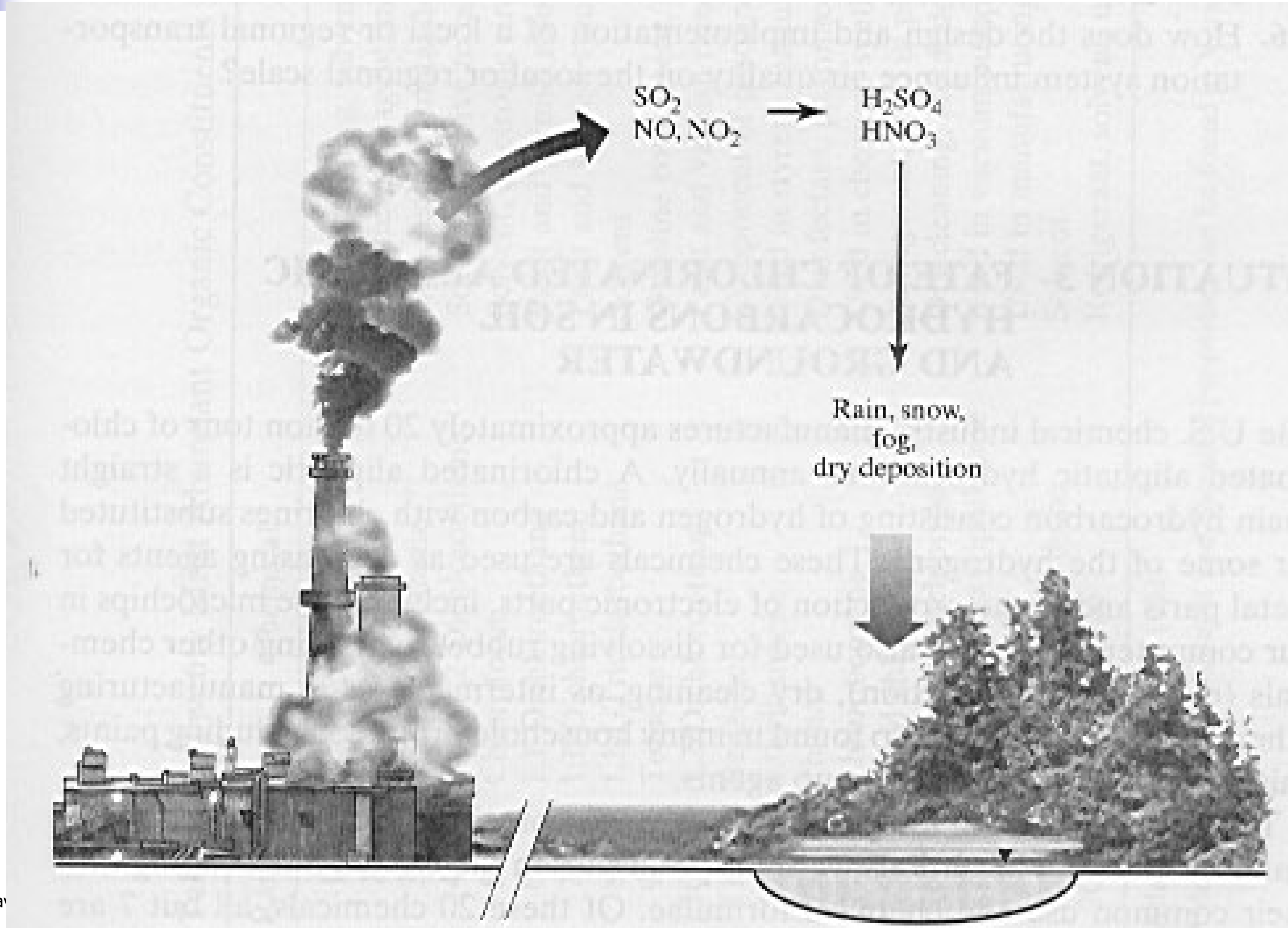
Situation #1: Municipal WWT

- Problem: you need to treat wastewater from a new suburban housing development
  - How do you design the plant?
    - Process types, tank sizes, N or P removal,
  - How do you operate the plant?
    - Treatment objectives, anaerobic or aerobic, seasonal variations, allow industrial users

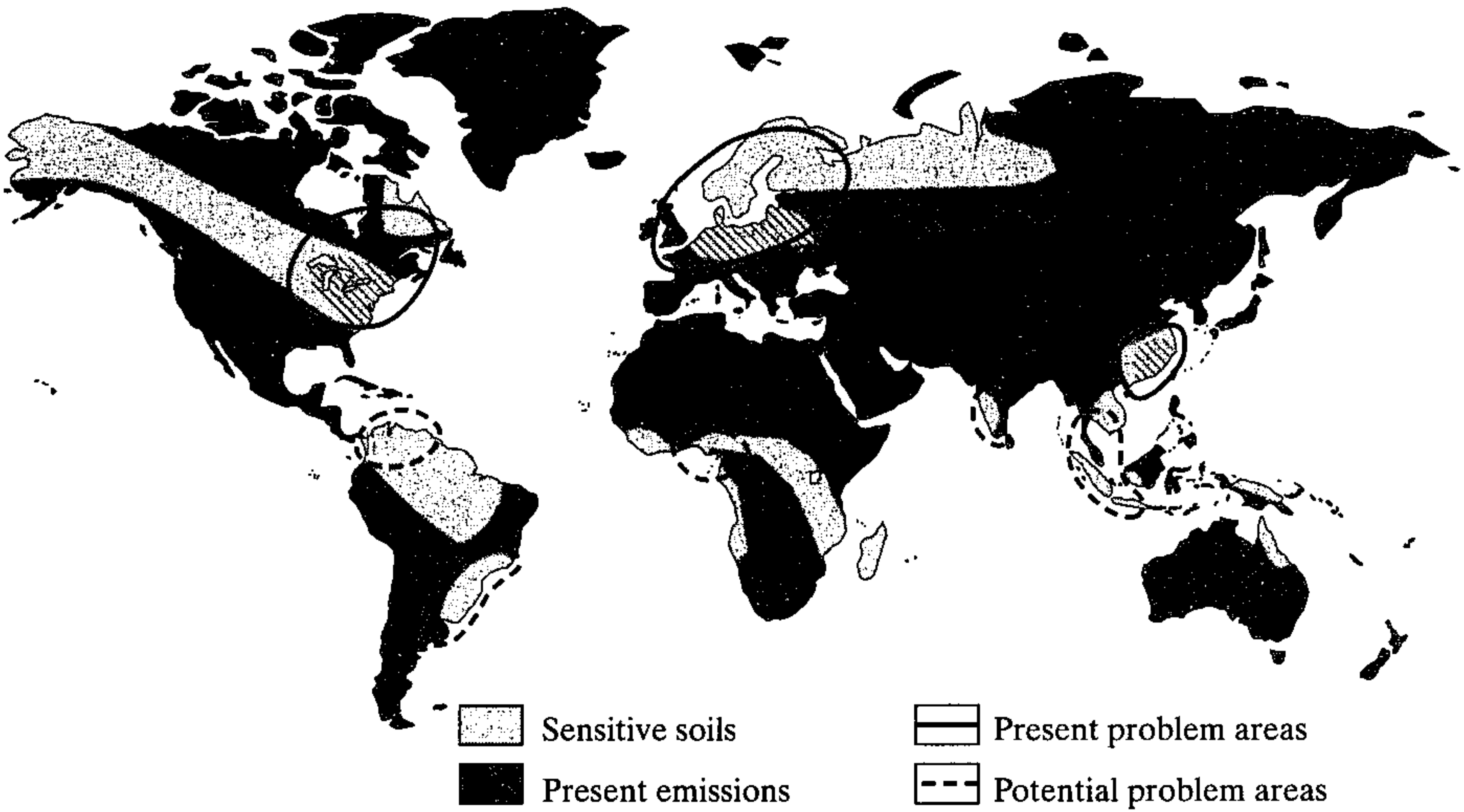
Conventional WW Treatment



Situation 2: Acid Rain



Global nature of acid rain



Air pollution issues

- How to remove sulfur and nitrogen oxides from stack gases
- What to do with the wastewater produced
- What happens with these gases get into the atmosphere
- How are the air pollution problems transported & who is affected
- What impact do these emissions have on natural water and aquatic life
- Regional solutions

Situation 3: VOCs in Soil

- Design & operation of treatment system
  - For soil, sediment, groundwater, leachate
- What type of system
  - Chemical, biological, physical
- What is the fate of the VOCs
- How quickly will they spread
- Will they form more toxic byproducts
  - Trichloroethene to vinyl chloride

Rank	Chemical	Use	Chemical Formula
1	Dichloromethane	Paint stripping, solvent degreaser, blowing agent in foams	CH_2Cl_2
2	Trichloroethene	Dry cleaning agent, metal degreaser solvent	C_2Cl_3H
3	Tetrachloroethene	Dry cleaning, metal degreaser, solvent, paint remover	C_2Cl_4
4	*trans* 1,2-Dichloroethene	Solvent, additive to lacquer, low-temperature solvent for caffeine	$C_2H_2Cl_2$
5	Chloroform	Solvent, electronic circuit manufacturing	$CHCl_3$
6	l,1-Dichloroethane	Paint and varnish remover, metal degreaser, ore flotation	$C_2C1_2H_4$
7	1,1-Dichloroethene	Paint and varnish remover, metal de-greaser	$C_2C1_2H_2$
8	1,1,1-Trichloroethane	Solvent	$C_2Cl_3H_3$
9	Toluene	Gasoline component, solvent thinner, adhesive solvent	C_7H_8
10	1,2-Dichloroethane	Paint and varnish remover, metal degreaser, fumigant	$C_2C_{12}H_4$

Rank	Chemical	Use	Chemical Formula
11	Benzene	Component of gasoline, used in chemical synthesis	C_6H_6
12	Ethylbenzene	Used in styrene manufacturing, solvent, asphalt construction	C_8H_{10}
13	Phenol	Disinfectant, pharmaceutical aid	C_6H_5OH
14	Chlorobenzene	Used in chemical synthesis	C_6H_5Cl
15	Vinyl chloride	Refrigerant, used in plastics industry	C_2ClH_3
16	Carbon tetrachloride	Dry cleaning, metal degreasing, veterinary medicine	CCl_4
17	Bis(2-ethylhexyl)phthalate	Used in vacuum pumps	$C_{24}H_{38}O_4$
18	Naphthalene	Used in manufacturing mothballs and motor fuel, component of coal tar	$C_{10}H_8$
19	1,1,2-Trichloroethane	Solvent	$C_2Cl_3H_3$
20	Chloroethane	Refrigerant, solvent, used to produce tetraethyl lead	C_2ClH_5

- How can we use our knowledge of physical & chemical properties?

Table 1-2. Properties of Selected Chlorinated Aliphatic Hydrocarbons*

Chemical	Vapor Pressure (mmHg)	Henry's Constant (atm-m^3/mole)	Water Solubility (mg/L)	Chemical Half-life (Years)
Carbon tetrachloride	90	0.0294	785	16–41
Chloroform	160	0.0040	8,200	742–3,000
Tetrachloroethene	14	0.0268	150	3.8×10^8–9.9×10^8
Trichloroethene	60	0.0117	1,100	4.9×10^5–1.3×10^6
Vinyl chloride	2,660	0.0224	2,700	>10

From Barbee, 1994.

*In later chapters, readers will learn about how these properties are used in evaluating and solving environmental problems.

From: Mihelcic, 1999

Information Sources

Field	Journal	Publisher
Environmental quality	*Environmental Science and Technology*	American Chemical Society
	Water Resources Research	American Geophysical Union
	Water, Air and Soil Pollution	Kluwer Academic Publications
Water treatment	*Journal of the American Water Works Association*	American Water Works Association
	Aqua	International Water Assn.
	Journal of the Environmental Engineering Division	American Society of Civil Engineers
Wastewater treatment	*Water Environment Research*	Water Environment Federation
	Journal of the Environmental Engineering Division	American Society of Civil Engineers
Solid waste	*BioCycle*	J. G. Press, Inc.
Hazardous waste	*Hazardous Waste and Hazardous Materials*	Mary Ann Liebert, Inc.
	Ground Water	Ground Water Publications, Inc.
Air pollution and control	*Journal of the Air and Waste Management Association*	Air and Waste Management Association
General	*Chemical and Engineering News*	American Chemical Society
	Civil Engineering	American Society of Civil Engineers

Books

- General Environmental Principles
  - Course text & supplementary references
- Water & Wastewater Treatment
  - Hammer & Hammer (or CEE 371 text)

•Government Sources

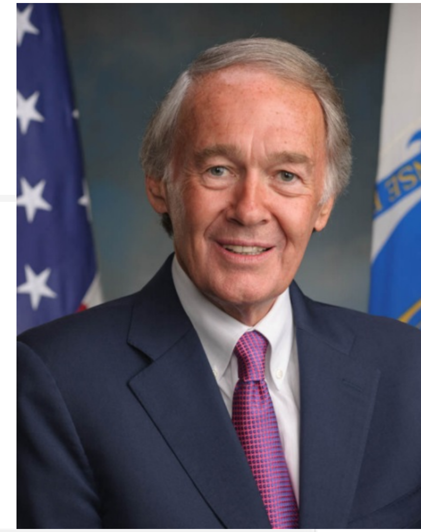
Source	Telephone Number	Address
Center for Environmental Research Information (CERI)	(513)569-7562	ORD Publications P.O. Box 19962 Cincinnati, OH 45219-0962
Superintendent of Documents	(202) 783-3238	Superintendent of Documents Government Printing Office Washington, DC 20402
RCRA Docket Information Center (RIC)	(800) 424-9346	RCRA Docket Information Center (RIC) Office of Solid Waste (OS-305) U.S. Environmental Protection Agency 401 M Street, S.W. Washington, DC 20460
National Technical Information Service (NTIS)	(703) 487-4650	National Technical Information Service U.S. Department of Commerce Springfield, VA 22161 Washington, DC

Laws and Regulations

- Laws: passed by a majority of both *legislative* houses and signed by the President
- Regulations: established by *executive* branch (USEPA) in response to laws
  - propose in Federal Register
  - public comment and modification
  - promulgation: into Code of Federal Regulations (CFR Part 40)

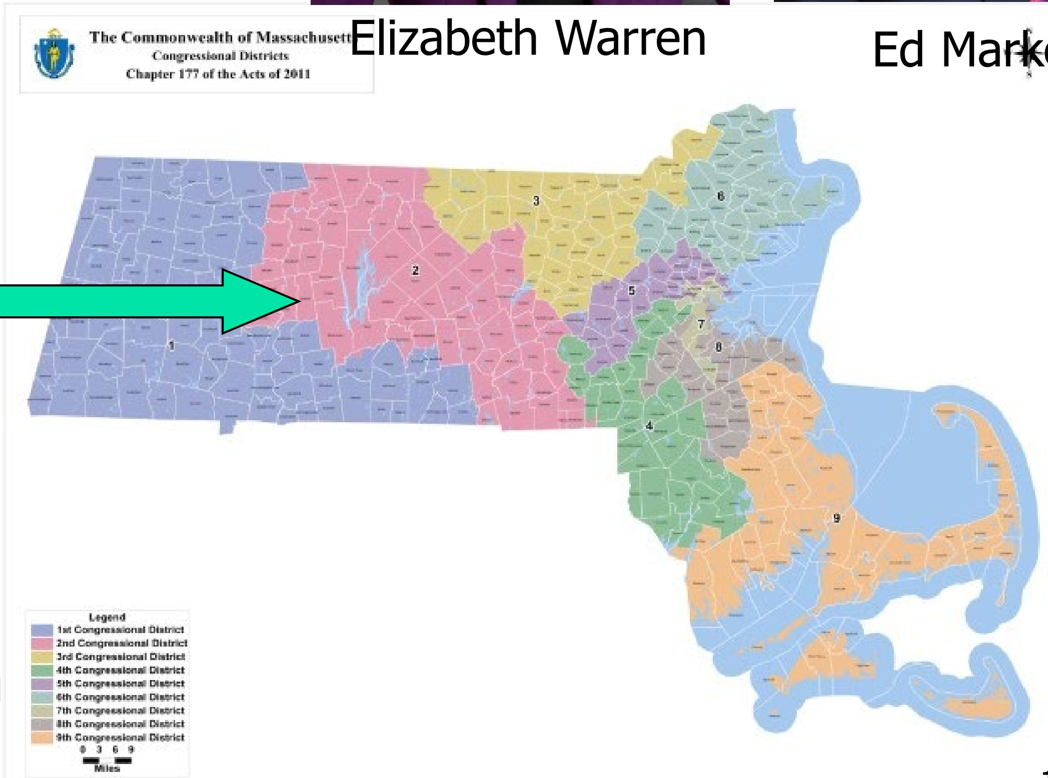
Our Delegation

Elizabeth Warren



Ed Markey

- House
  - James McGovern



1972: Federal Water Pollution Control Act

An "act" of Congress = a law

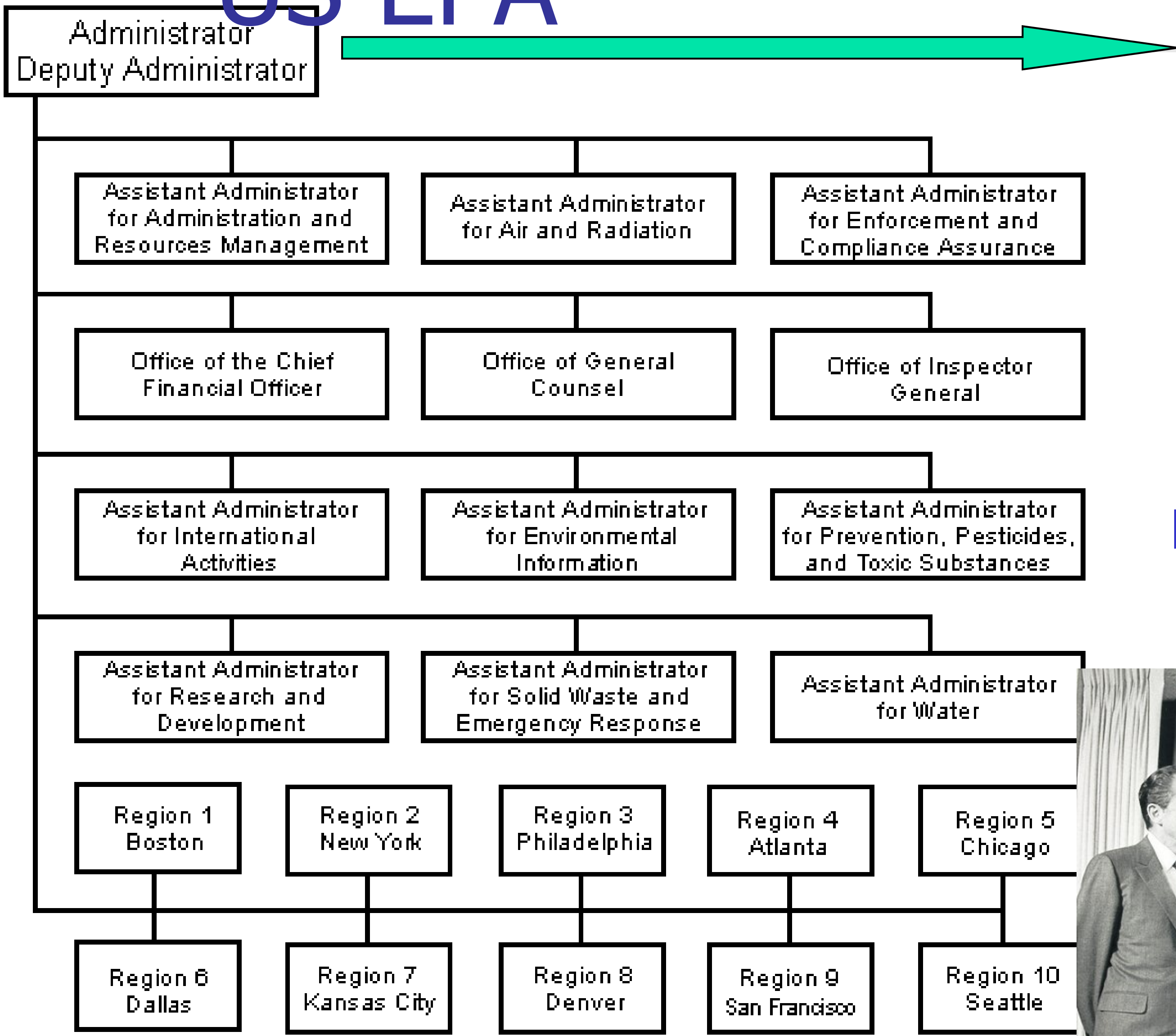
- PL 92-500 subsequently amended and now called the Clean Water Act
  - established water quality goals "fishable & swimmable" and timetable
  - established National Pollution Discharge Elimination System (NPDES)
  - construction grants for WW treatment
- Eventually required secondary treatment (30/30)
  - 30 mg/L BOD_5
  - 30 mg/L TSS

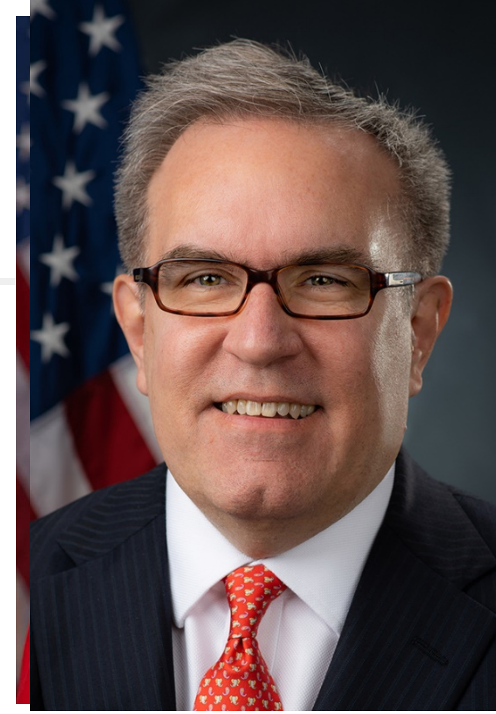
Laws: where to find them

- Daily
  - Federal Register
    - Back to 1994: on-line
      - http://www.gpoaccess.gov/fr/index.html
    - Pre 1994: see Gov Docs in DuBois
- Annual summary (July)
  - Code of Federal Regulations (CFR)
    - Back to 1996/7: on-line
      - http://www.gpoaccess.gov/cfr/index.html
    - Pre 1996/7: see Gov Docs in DuBois

Andrew Wheeler

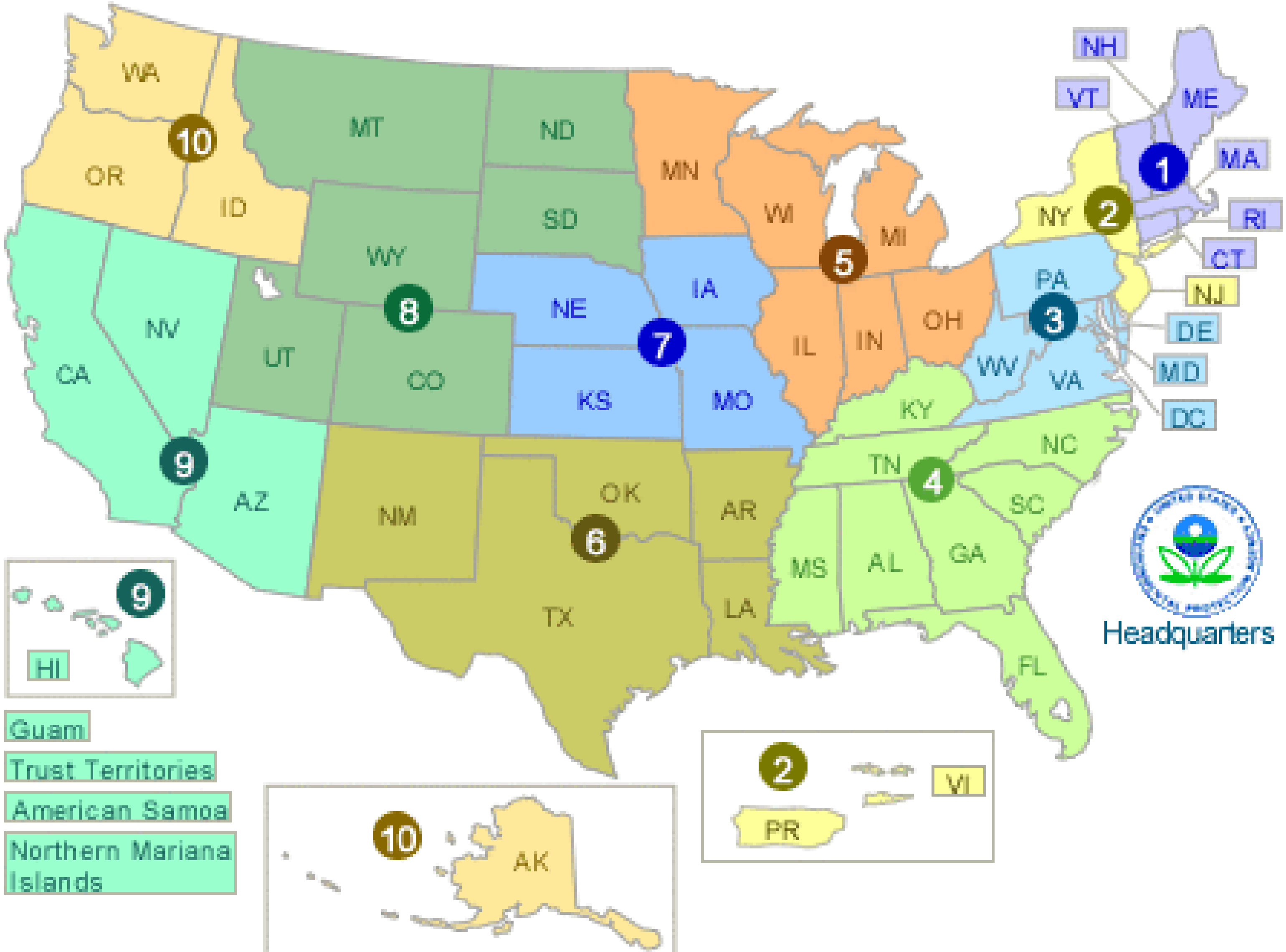
US EPA





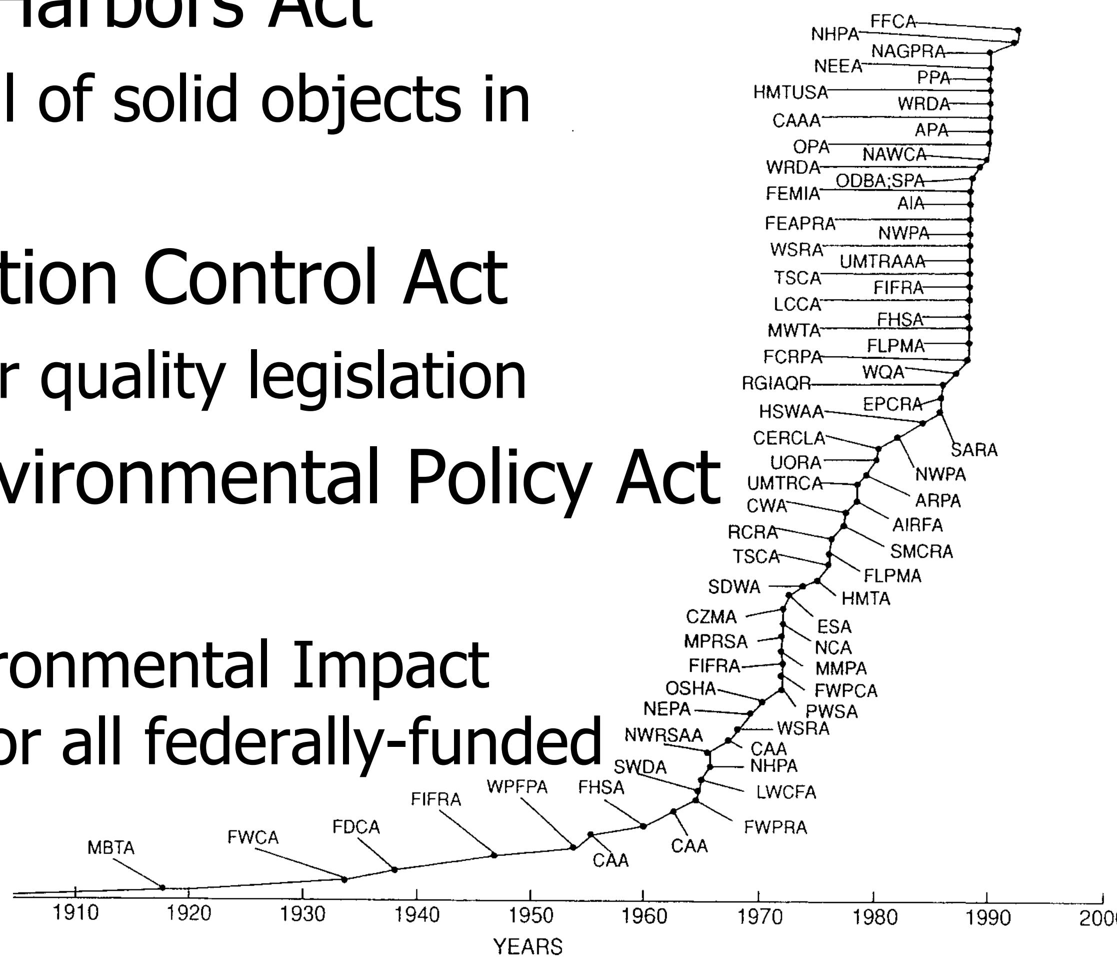
- Created by Nixon Adm

USEPA Regions



Legislative History

- 1899: Rivers and Harbors Act
  - Prohibited disposal of solid objects in navigable waters
- 1948: Water Pollution Control Act
  - first national water quality legislation
- 1970: National Environmental Policy Act (NEPA)
  - required and Environmental Impact Statement (EIS) for all federally-funded projects



FEDERAL ENVIRONMENTAL LEGISLATION

Legislative History

- 1970: USEPA formed
- 1972: Federal Water Pollution Control Act
  - PL 92-500 subsequently amended and now called the Clean Water Act
  - established water quality goals "fishable & swimable" and timetable
  - established National Pollution Discharge Elimination System (NPDES)
  - construction grants for WW treatment
  - Required industry-specific WW treatment technology
    - BPT: best practicable technology by 1977
    - BAT: best available technology by 1983

Legislative History (cont.)

- 1970: Clean Air Act
  - national air quality standards
  - amended several times since (‘77 ‘90)
- 1974: Safe Drinking Water Act
  - set national drinking water standards
  - amended may times since
- 1976: Toxic Substances Control Act (TSCA)
  - regulate new hazardous chemicals (e.g. PCBs)

Legislative History (cont.)

- 1976: Resource Conservation and Recovery Act (RCRA)
  - protect air, water and land from solid and hazardous wastes
  - defines hazardous wastes
- 1977: Clean Water Act Amendments
  - Best conventional pollutant technology (BCT)
  - Secondary treatment: 30 mg/L BOD_5 30 mg/L TSS
  - Priority Pollutants (127 toxic compounds)
- 1980: Comprehensive Environmental Response, Compensation and Liabilities Act (CERCLA or Superfund)
  - established fund and mechanisms for cleaning existing hazardous waste sites

Regulatory Methods

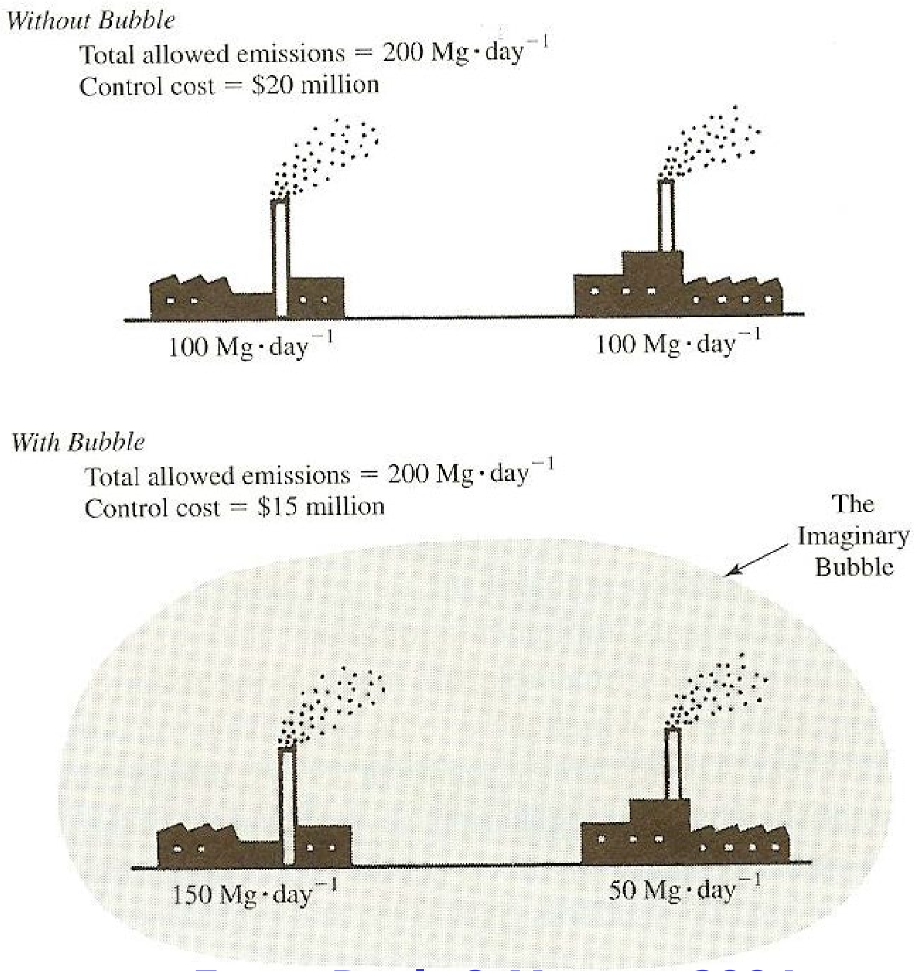
- Environmental Quality-Based Standards
  - cannot degrade environment beyond a certain level
  - dependent on immediate environment
  - more flexible
- Effluent-Based Standards
  - cannot discharge above a certain level of pollutant
  - independent of immediate environment
  - easier to establish and monitor

"Controlled Trading"

- Bubble Policy

"Environmental rules now regulate each of the different processes in a plant. With this new policy we will draw an **imaginary bubble** around the whole plant and tell the company that it can find the most efficient way of controlling the plant's emissions as a whole. If it costs a dollar to control a pound of particulate pollution from one machine and fifty cents from another, the plant manager will quite reasonably choose to control fewer $1 pounds and more 50 cent pounds. If the plant engineer can find a new way of reducing particulate emissions from a third machine for 30 cents a pound, he will remove as many of these pounds as he can in preference to either the 50 cent or one dollar pounds. As long as no more particulates escape from the overall bubble than before, the company's engineers can continue to innovate."

Douglas Costle, EPA Administrator, 1979



From: Davis & Masten, 2004

Controlling Air Pollution in Cities

Source	Pollutants	Methods of Control
Industries	Volatile organics	Require reduced emissions
	Volatile chlorofluorocarbons	Require reduced emissions
	Particulate inorganics	Require reduced emissions
Automobiles	Hydrocarbons	Improved discharge nozzles at filling stations, improved ventilation within the gasoline tank
	Products of incomplete combustion	Improved combustion by requiring improved combustion efficiency (auto manufacturer), regular engine maintenance by requiring vehicle emission testing, requiring gasoline stations to provide only oxygenated fuels.
	Chlorofluorocarbons from air conditioners	Require the redesign of the air conditioner so that future automobiles can use other refrigerants.

Table 2.2 in Ray (pg 18)

Basis for Setting Standards

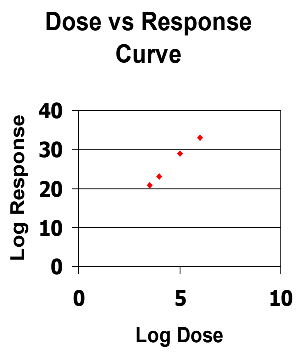
- Experimentation
  - animal testing, human exposure
- Attainability
  - economic & technical feasibility
- Established practice
- Risk Assessment

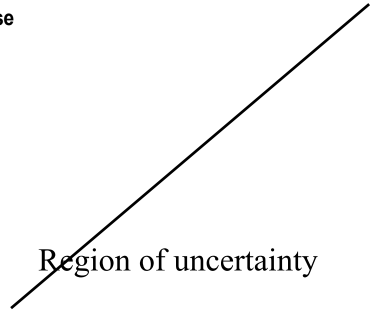
Definitions

- Risk: the probability of occurrence of adverse health effects in humans
- Risk Assessment: the process of characterizing the nature and probability of adverse health effects of human exposure to environmental hazards
- Risk Management: the process of evaluating and selecting among alternative regulatory actions

Four steps in a Risk Assessment

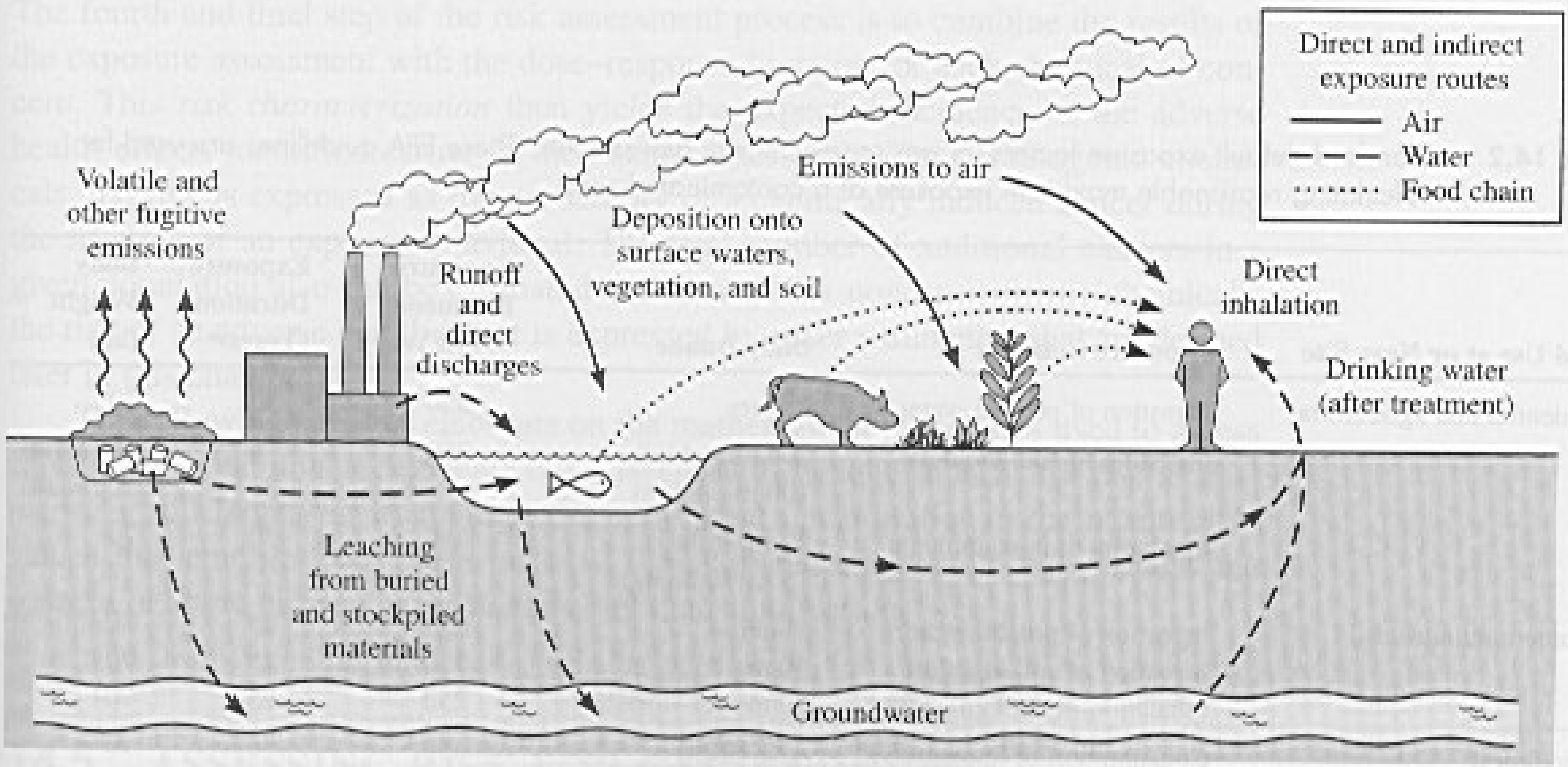
- Hazard Identification
  - what is it?
- Dose Response
  - see graph
- Human Exposure
  - actual doses and routes
- Risk Characterization





Routes of exposure

From: Rubin, 2001

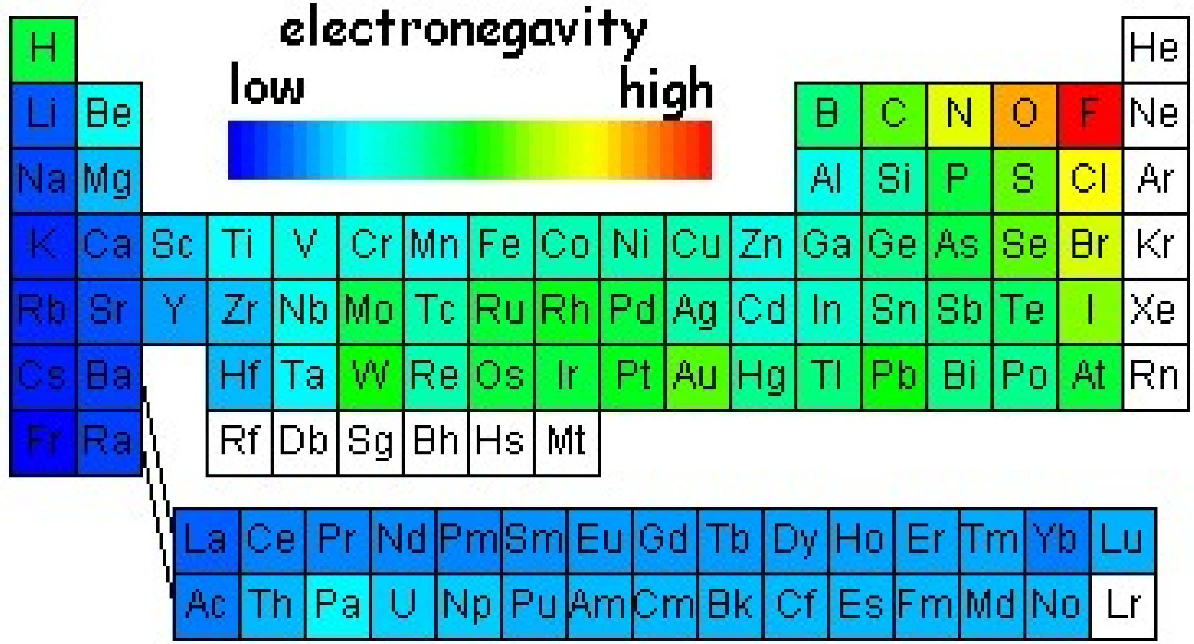


Comparative Risks

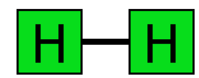
All increase chance of death in any year by 0.000001

Smoking 1.4 cigarettes	Cancer, heart disease
Spending 1 hr. in a coal mine	Black lung disease
Living 2 days in NYC or Boston	Air pollution
Living 2 months in Denver	Cancer caused by cosmic radiation
One chest X-ray	Cancer caused by radiation
Eating 40 tbs. of peanut butter	Liver cancer caused by Aflatoxin B
Drinking 30 12-oz. cans of diet soda	Cancer caused by saccharin
Living 150 yrs. within 20 miles of a nuclear power plant	Cancer caused by radiation

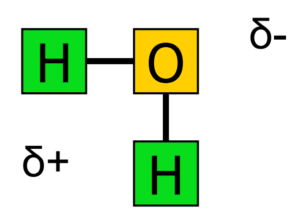
Bonds



- Non-Polar Covalent bond
  - Electrons are perfectly shared between atoms



- Polar Covalent bond
  - Electrons shared but not equally



- Ionic bond
  - Electrons are entirely associated with one of the atoms
    - The more electronegative one

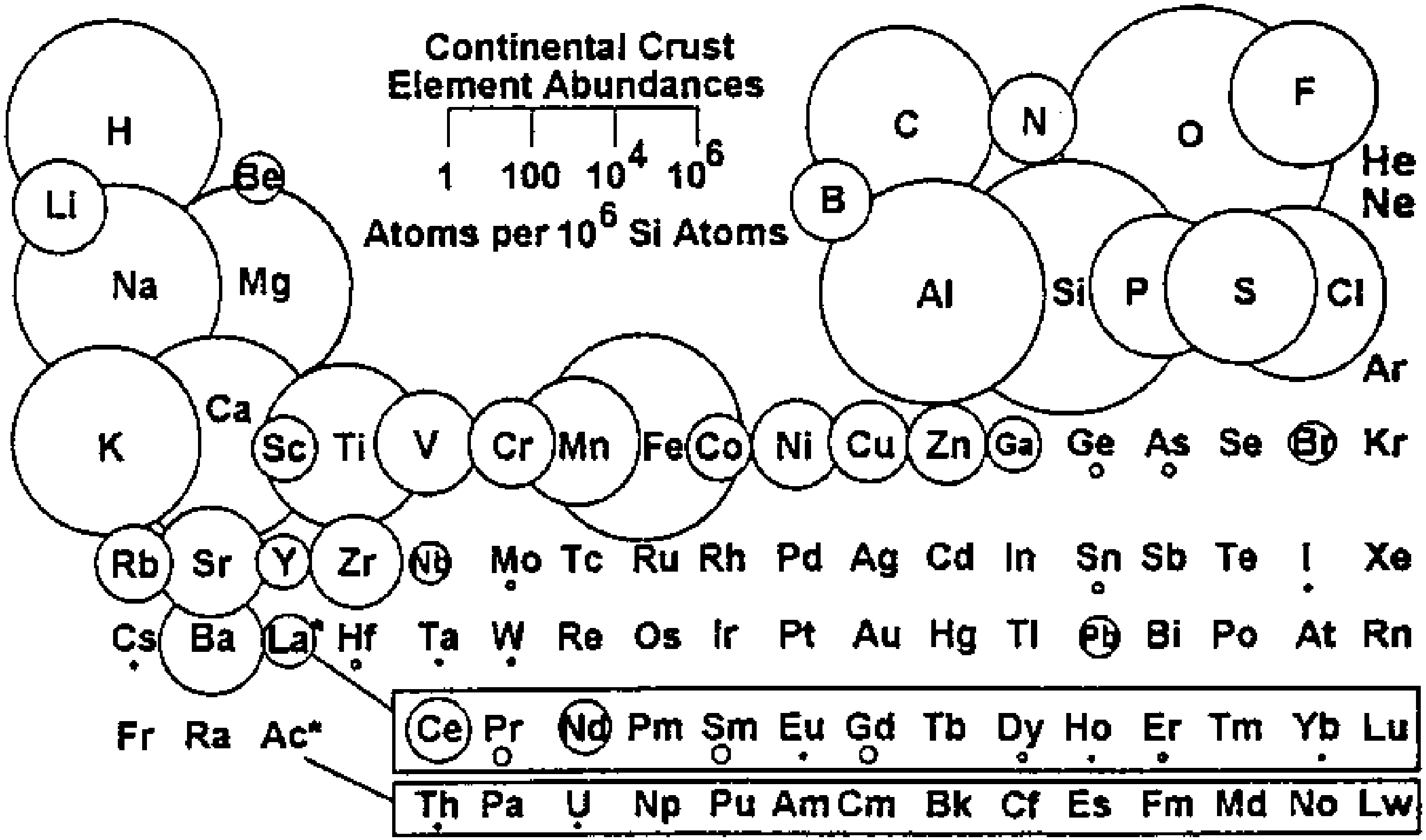
Isotopes

Chart of the Nuclides

(Including the first 8 elements up to Oxygen)

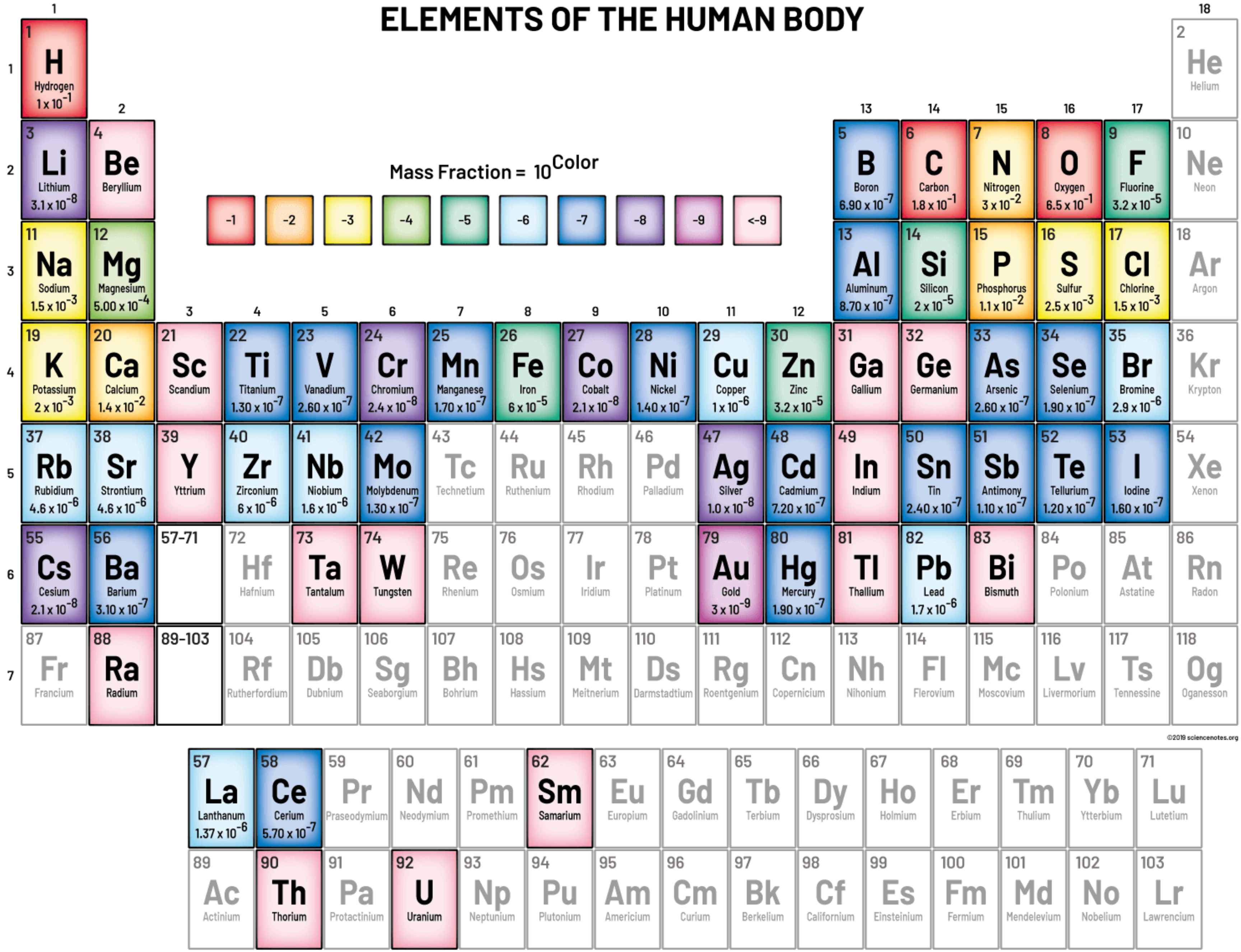
protons \ neutrons	0	1	2	3	4	5	6	7	8	9	10	11	12
8						O 13 .0087s	O 14 71s	O 15 124s	O 16 99.759	O 17 0.037	O 18 0.204	O 19 29s	O 20 14s
7						N 12 0.011s	N 13 9.96m	N 14 99.63	N 15 0.37	N 16 7.1s	N 17 4.14s	N 18 0.63s	
6				C 9 0.13s	C 10 19s	C 11 20.5m	C 12 98.89	C 13 1.11	C 14 5730y	C 15 2.25s	C 16 0.74s		
5				B 8 0.78s	B 9 $3x10^{-19}$s	B 10 19.78	B 11 80.22	B 12 0.020s	B 13 0.019s				
4			Be 6 $4x10^{-21}$s	Be 7 53d	Be 8 $3x10^{-16}$s	Be 9 100	Be10 $2.7x10^{6}$y	Be11 13.6s	Be12 0.011s				
3			Li 5 10^{-21}s	Li 6 7.42	Li 7 92.58	Li 8 0.85s	Li 9 0.17s						
2		He 3 .00013	He 4 100	He 5 $2x10^{-21}$s	He 6 0.81s		He 8 0.122s						
1	H 1 99.985	H 2 0.015	H 3 12.26y										

Elemental abundance in crust



- O
- Si
- Al
- Fe
- Ca
- Na
- Mg
- K
- Ti
- H
- P
- Mn
- F

ELEMENTS OF THE HUMAN BODY



Tom Brady

- Gillette Stadium, Sunday

NFL NCAAF MLB NBA FANTASY SOCCER NHL MORE SUBSCRIBE

The MMQB Archive Scores Schedule Standings Teams Stats Fantasy

NFL | MMQB | NFL WEEK 1

Tom Brady, Patriots Steamroll Steelers to Make Early-Season Statement

Microcystis aeruginosa

- Seneca Lake NY, Friday

WENY NEWS

NEWS WEATHER SPORTS FEATURES CONTESTS ON T

Harmful Algal Blooms found in Seneca Lake

Friday, September 6th 2019, 10:51 AM EDT by Caitlin Murphy

1/3

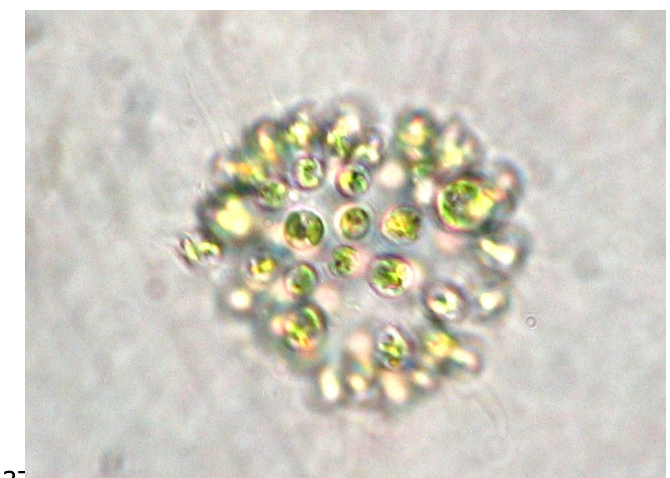
Tom vs Miocrocystis

Tom Brady

- 70,514 passing yards
- 96×10^3 g
  - 58% water
  - 42% dry
- 3 offspring in 42 yrs

Microcystis aeruginosa

- No passing yardage
- 2.2×10^{-11} g
  - 76% water
  - 24% dry
- 10^{563} offspring in 42 years

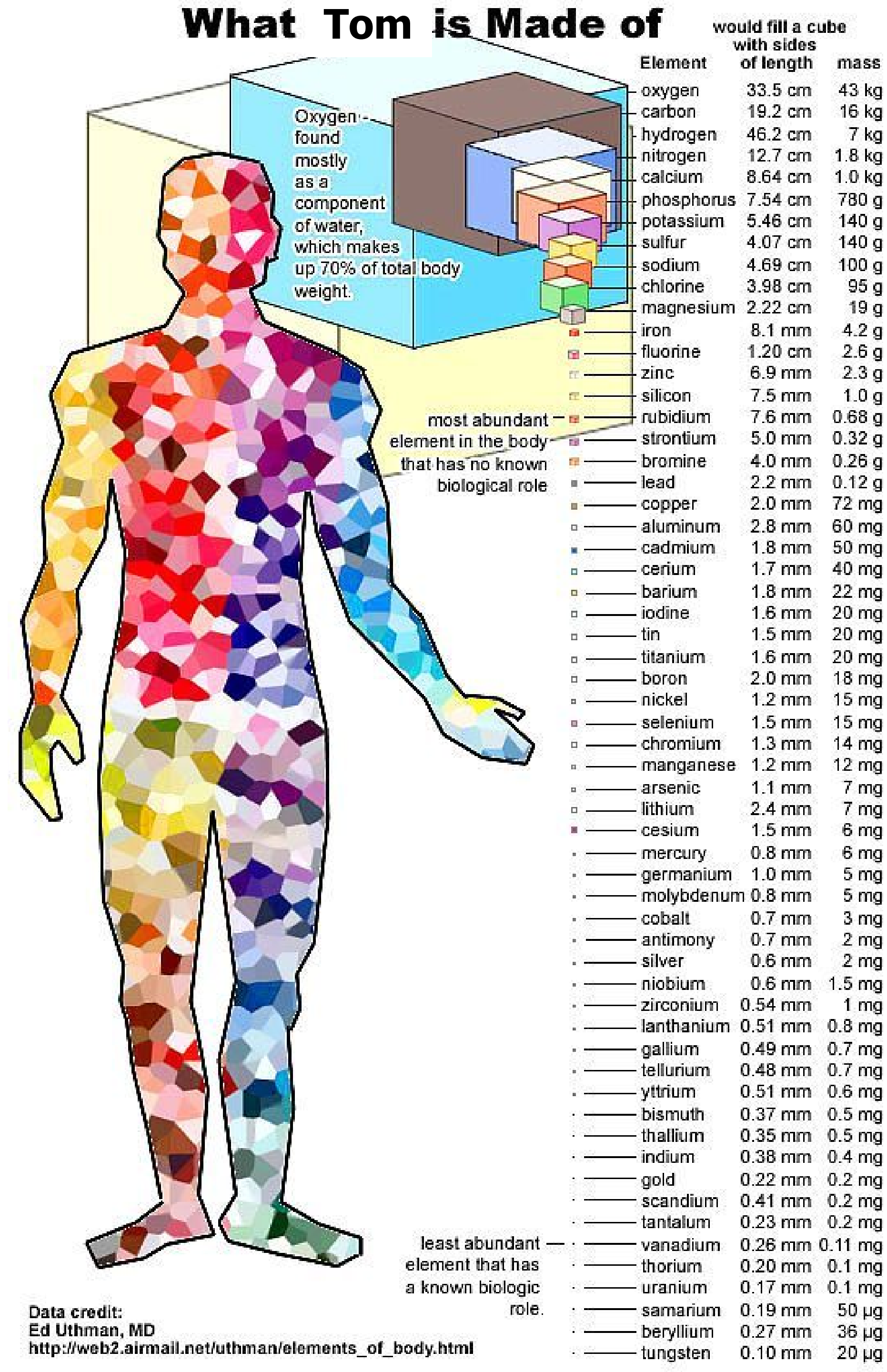


SI Unit prefixes (large)

Factor	Prefix	Symbol
10^1	deka	da
10^2	hecto	d
10^3	kilo	k
10^6	mega	M
10^9	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E

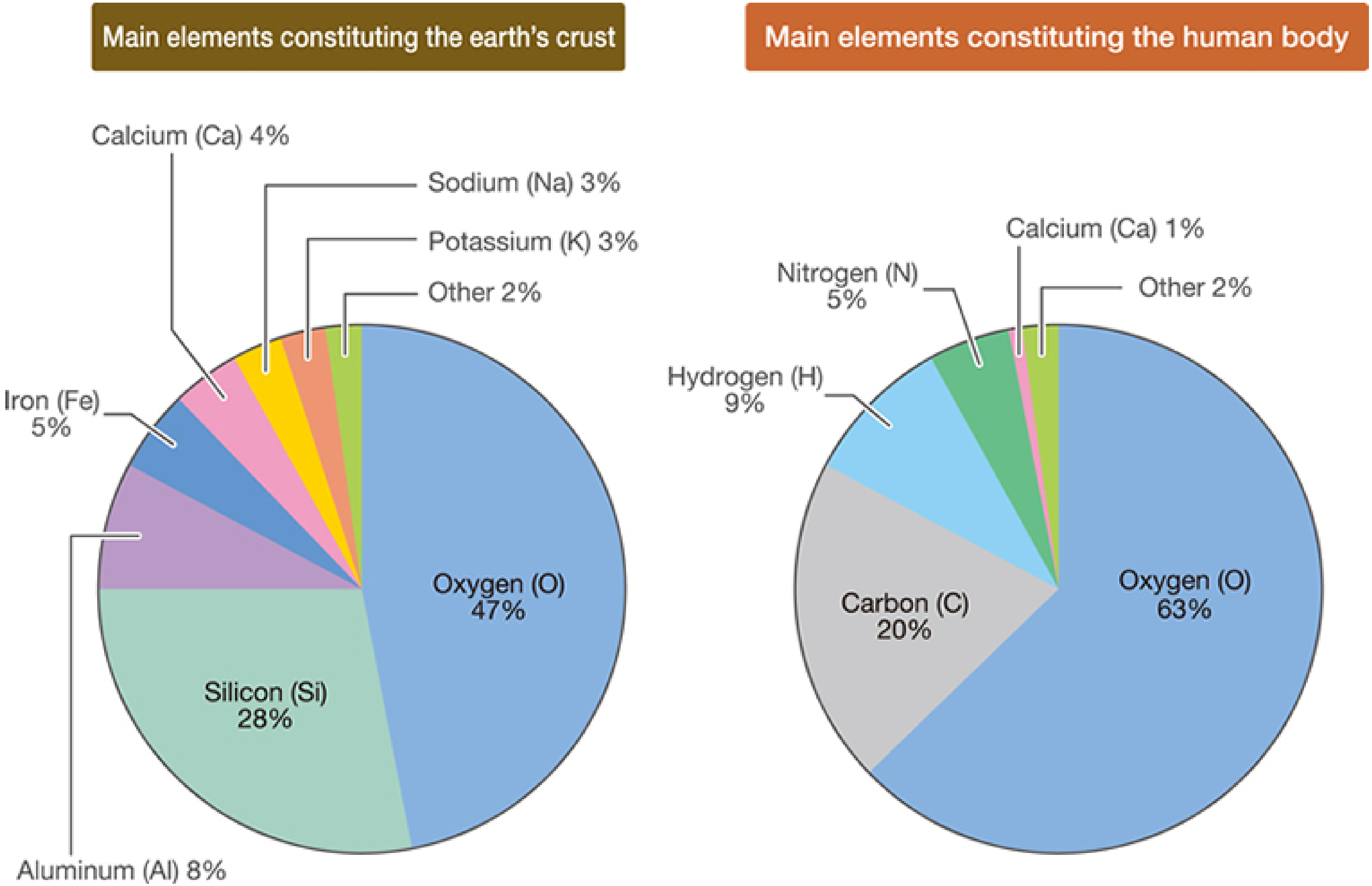
SI Unit prefixes (small)

Factor	Prefix	Symbol
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a



Tom vs Microctys.

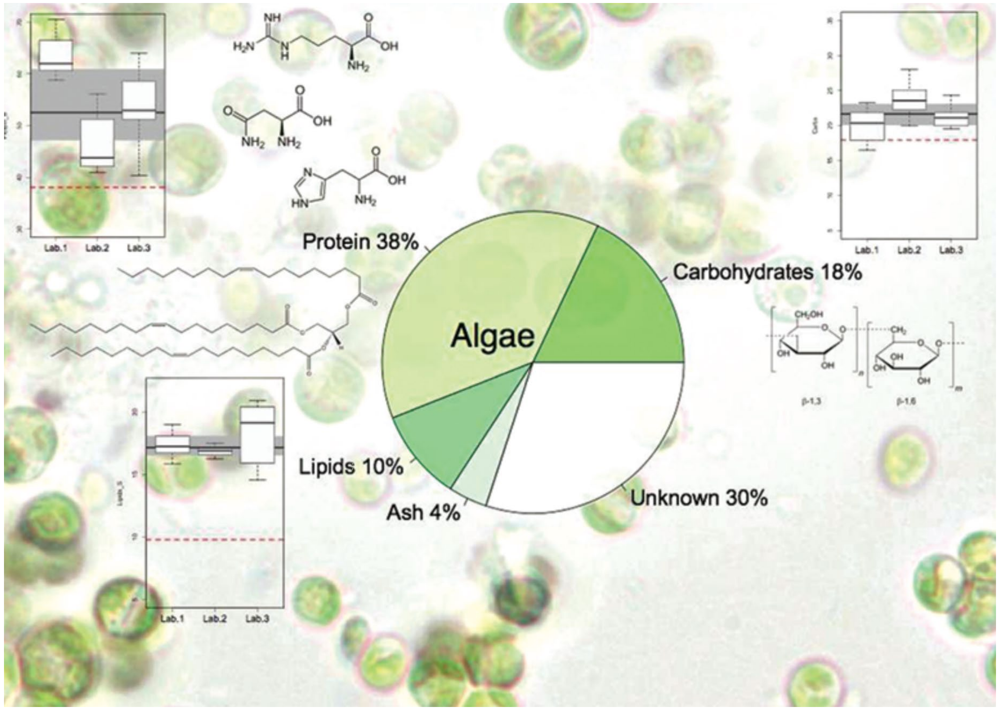
Element	mM/L	M/M-P
C	11000	147
N	1400	16
P	120	1
S	170	1.3
K	250	1.7
Mg	100	0.56
Ca	3100	23
Sr	7	0.054
Fe	0.7	0.0075
Mn	0.42	0.0038
Zn	0.08	0.0008
Cu	0.035	0.00038
Co	0.024	0.00019
Cd	0.017	0.00021
Mo	0.0031	0.000033



Main elements constituting the earth's crust
Calcium (Ca) 4%
Sodium (Na) 3%
Potassium (K) 3%
Other 2%
Iron (Fe) 5%
Oxygen (O) 47%
Silicon (Si) 28%
Aluminum (Al) 8%
Main elements constituting the human body
Calcium (Ca) 1%
Nitrogen (N) 5%
Other 2%
Hydrogen (H) 9%
Oxygen (O) 63%
Carbon (C) 20%

Algae

- dsa



Laurens et al., 2012 [Anal. Chem. 84:1879]

- To next lecture