Medical Geology and Research on Environmental Health

(Effects of Metals)

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Environmental Health

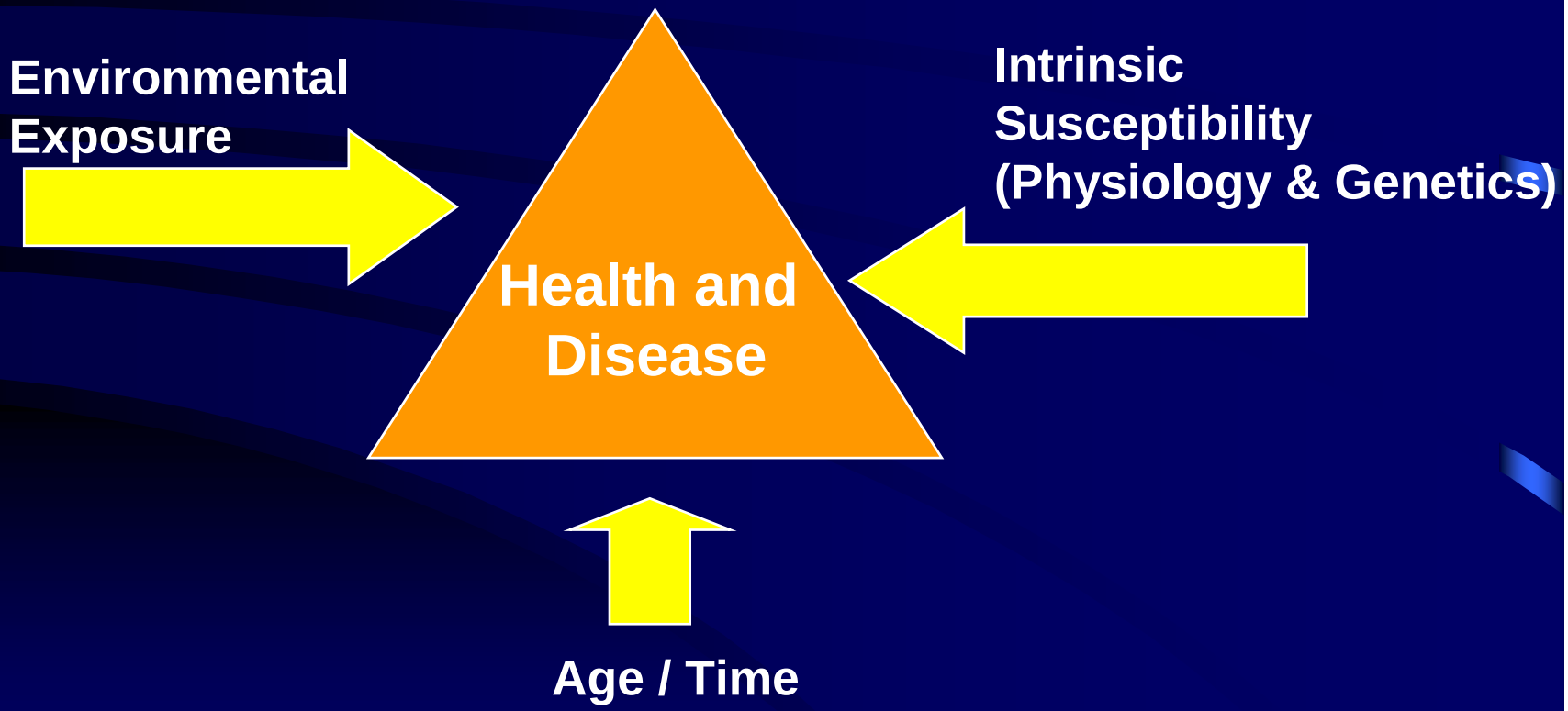
"In its broadest sense, environmental health comprises those aspects of human health, disease and injury that are determined or influenced by factors in the environment.

This includes not only the study of the direct pathological effects of various chemical, physical and biological agents, but also the effects on health of the broad physical and social environment, which includes housing, urban development, land-use and transportation, industry and agriculture".

-Healthy People 2010

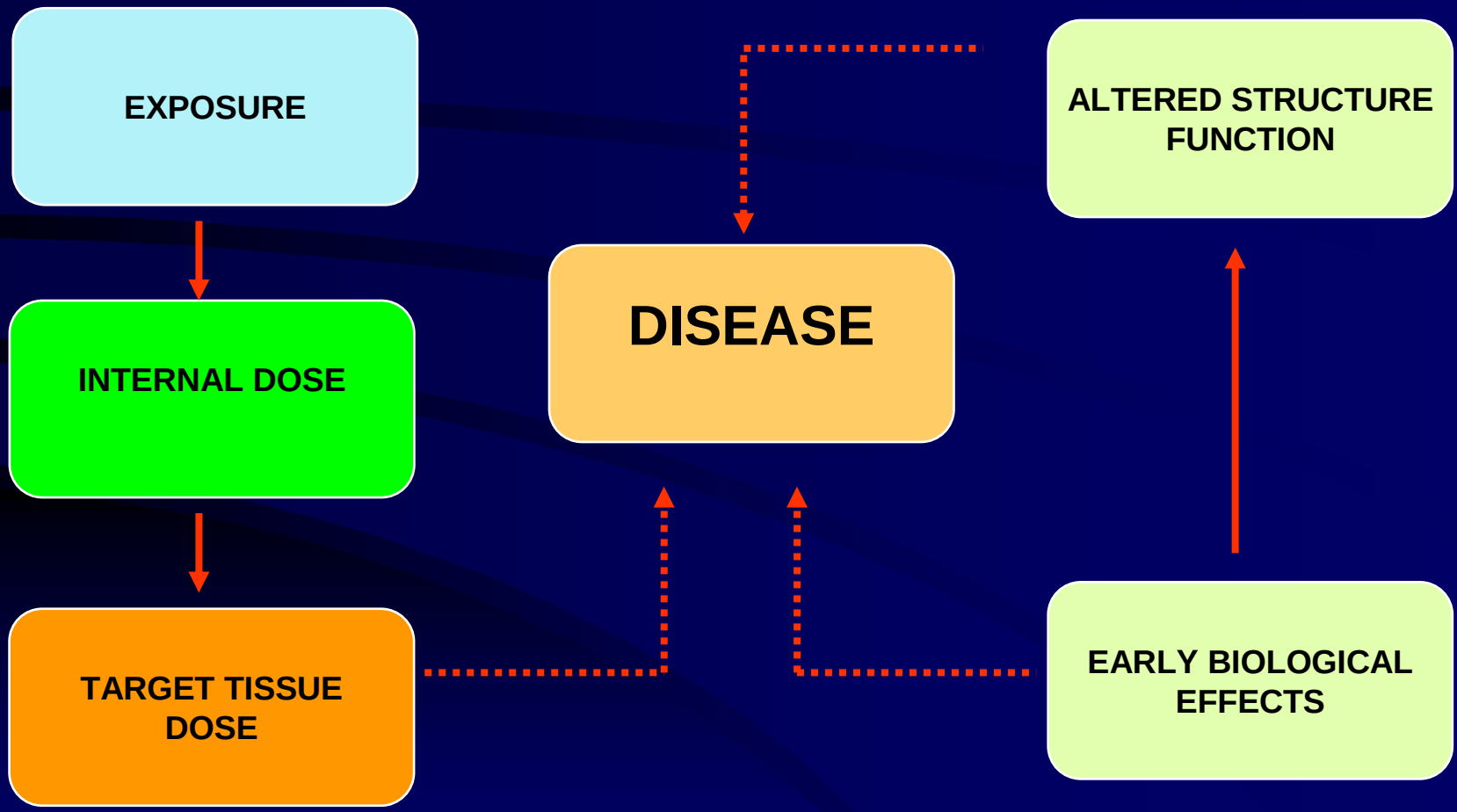
Environmental Health

An Approach to the Study of Human Diseases



Environmental Exposure and Risk of Disease

Traditional Approach

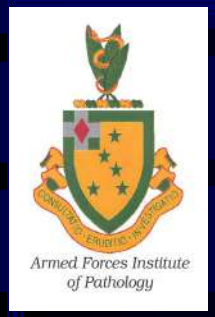


Metals (and metalloids) affect many targets

- **Lead: brain, blood formation**
- **Mercury: brain, heart function**
- **Nickel and chromate: allergy, cancer**
- **Cadmium: kidneys**
- **Arsenic: skin, bladder, liver, kidneys**
- **Several metals: cancer risk**

Risk Assessment Issues Related To Metals

- Different valence states of metals and different metal compounds produce different health and/or carcinogenic response.
- Metals are part of the background.
- Animal and human responses are not consistent.
- Variation in individual susceptibility.
- Bioavailability vs Bioaccessibility of metals.



Different *Valence States* of Metals and Metal Compounds

- Not every valence state of the metals known to be carcinogenic in humans has been associated with an increased risk of cancer (e.g., Cr^{3+}, As^{0}, metallic nickel).
- Various theories exist about the carcinogenicity of different metal compounds (e.g., solubility).

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Metals Are Part of the Background

- Human exposure to metals is only partly anthropogenic. Metals, including carcinogenic metals, are naturally found as part of the earth's crust, in the air and water, and in food.
- Arsenic in drinking water occurs in numerous places in the world as a result of a geochemical phenomenon at exposures high enough to produce health effects including cancer.

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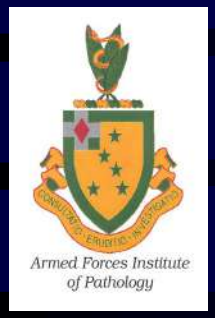
Animal and Human Responses are not Consistent

- Few animal studies report a carcinogenic response by inhalation or ingestion of the metals known to be carcinogenic in humans (e.g., arsenic shows little if any carcinogenic response by any route in animals; chromium and nickel demonstrate strong responses by bronchial implantation in animals, but little by inhalation or ingestion).
- Assessment of the carcinogenic risk of metals for humans is based on human data, including dose-response assessment.



There is Evidence of Variation in Individual Susceptibility to Certain Metals *(Arsenic as an Example)*

- Whites may be more susceptible to arsenic induced skin cancer.
- Smokers may be at greater risk or arsenic-induced or chromium-induced lung cancer.
- Diet appears to have an effect on arsenic-induced skin cancer (poorer diets have greater risk of disease)
- Risk assessment needs to consider those at greater risk as well as the risk of the general population.

The Importance of Bioavailability

- "The rate and extent to which a substance is absorbed and becomes available at the site of drug action".

- Ex. Bioavailability of "lead"
  - **Adults** absorb about 5-15% of ingested lead, usually retaining less than 5% of absorbed lead
  - **Children** absorb about 41.5% of ingested lead, which is related age and development of GI tract.

Bioavailability (cont.)

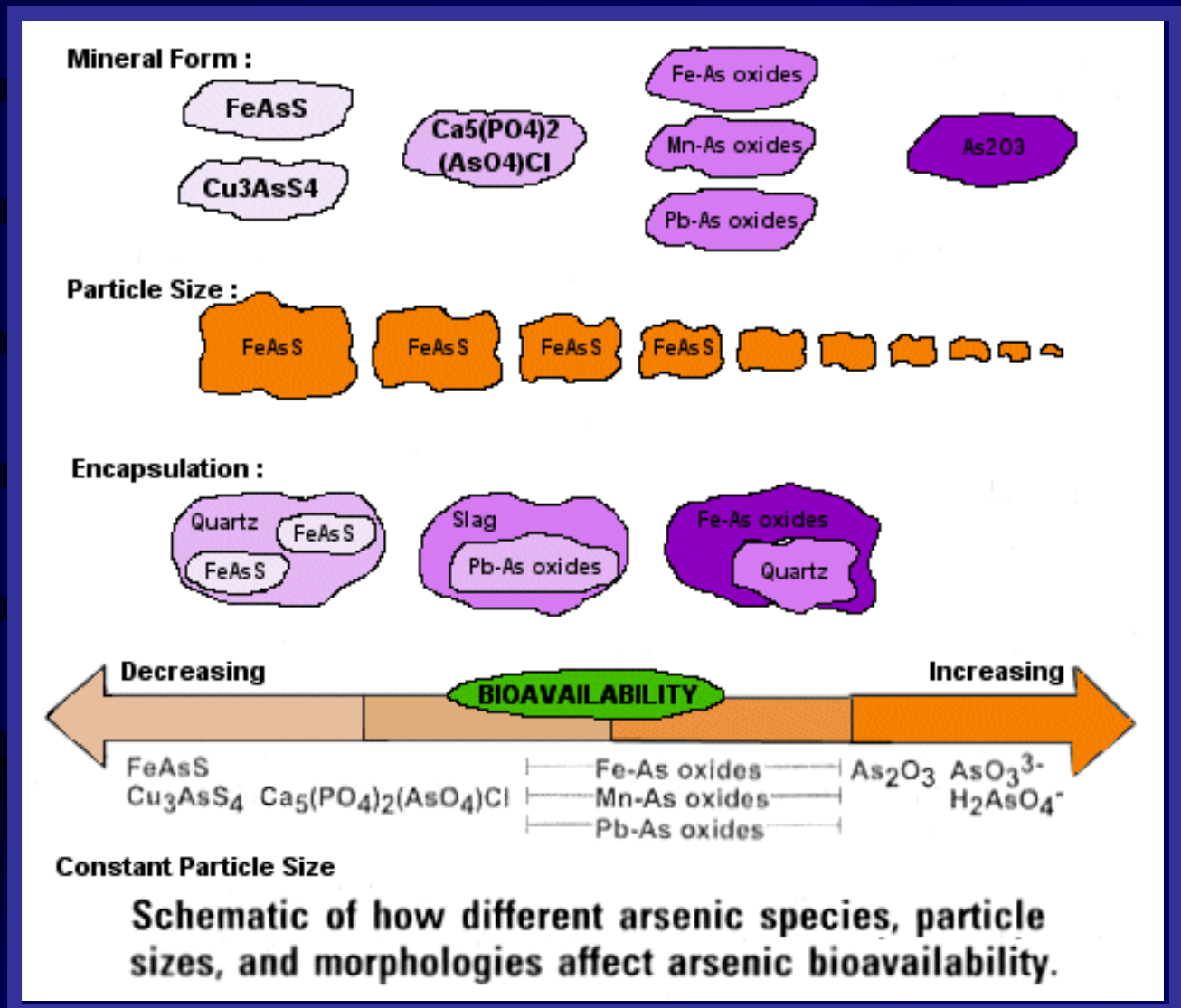
- Nutritional and dietary factors influence “lead” toxicity
  - Low dietary iron and calcium enhance lead absorption.
- Vitamin C reduces “lead” absorption
  - Increases iron absorption, decreasing the ability of lead to compete for binding

What is bioaccessibility ?

Bioaccessibility - the fraction that is soluble in the gastrointestinal environment and is available for absorption.

The Importance of Bioaccessibility
Ex. Arsenic in Soils

- typically between 10 and 30% of arsenic in the soil is bioaccessible
- risk assessments assuming 100% bioaccessibility will overestimate exposure
- this could lead to overestimates of risk and remediation or limitations on development



Schematic of how different arsenic species, particle sizes, and morphologies affect arsenic bioavailability.

(After Ruby *et al*., 1999)

Medical Geology and Human Health

General Research Priorities

- **To study trace elements, especially their bioaccessibility, bioavailability, geo-availability;**
- **To establish baseline or background levels… natural occurrence and distribution.**
- **To implement the use of geographic, biomedical, pathological, epidemiological and toxicology tools to obtain a better understanding on the distribution, mobility and levels of toxic trace elements.**

Medical Geology and Human Health

General Research Priorities (cont.)

- **Weather-related morbidity;**
- **Water- and vector-borne diseases;**
- **Assessment of natural and ambient sources of mercury and arsenic (i.e., health effects due to coal combustion, contaminated food, soil, and water)**

Natural and Mineral Dust

Water-Borne Diseases

Volcanic Emissions

Medical Geology

Links to Human Diseases

Health Effects

Trace Elements/Toxic Metals

(I.e., DU, Ra, Pb, As, Hg)

Cancer

(prostate, breast)

Emerging Infectious Diseases

Considerations for Conducting Environmental Health Studies of Metals

- Sources of data (e.g., mortality data, incidence data, personnel records)
- Effect being studied (lung cancer, skin cancer, etc.)
- Designs for study (e.g., prospective, case-control, cross-sectional)
- Confounding (e.g., smoking and lung cancer, other carcinogens)
- Latency period from exposure till disease
- Exposure information
- Statistical power (considers background disease rate, size of population being studied, etc.)
- Species of metal (e.g., valence, compound, etc.)

Environmental exposures follow complex pathways

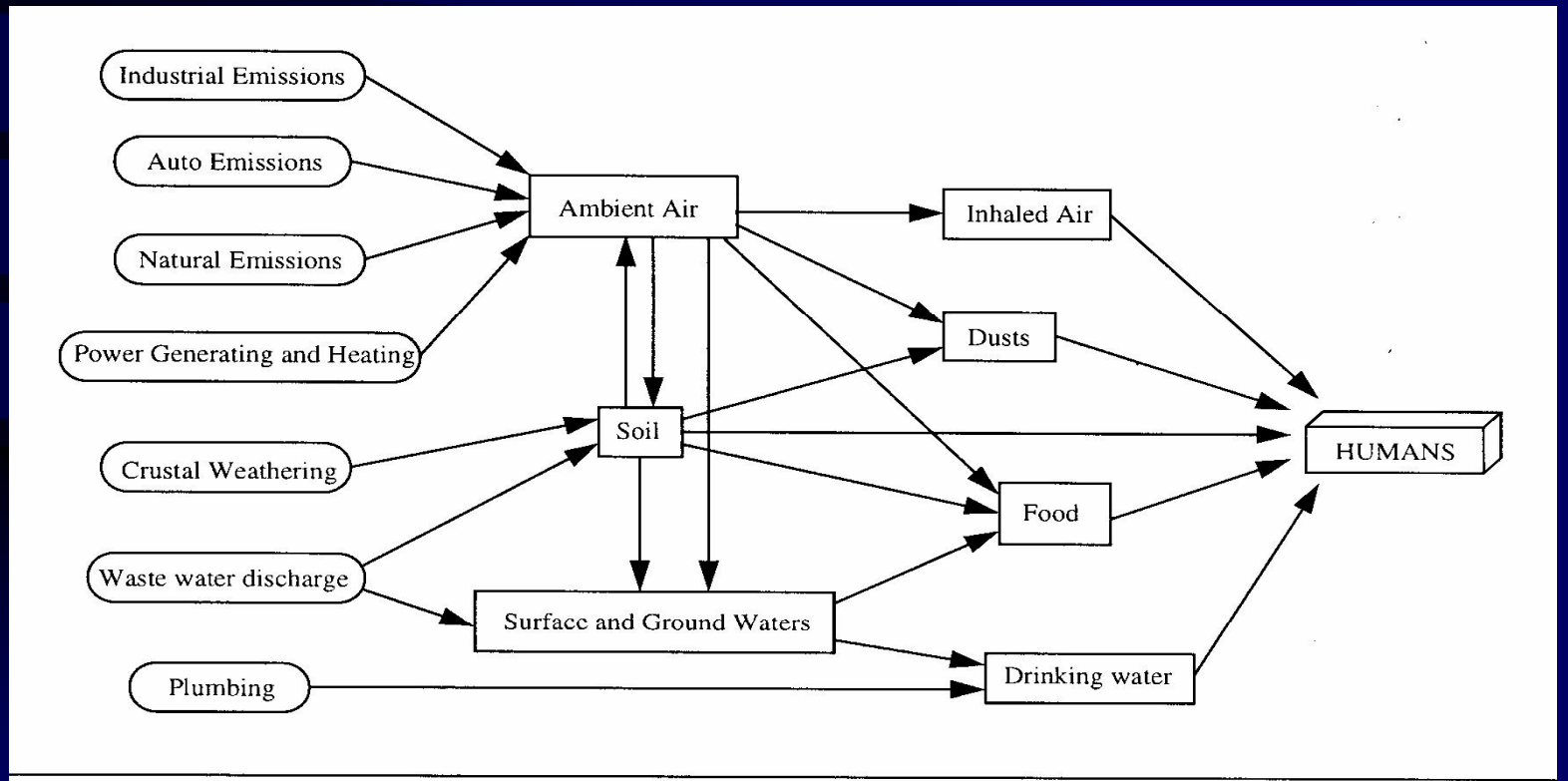
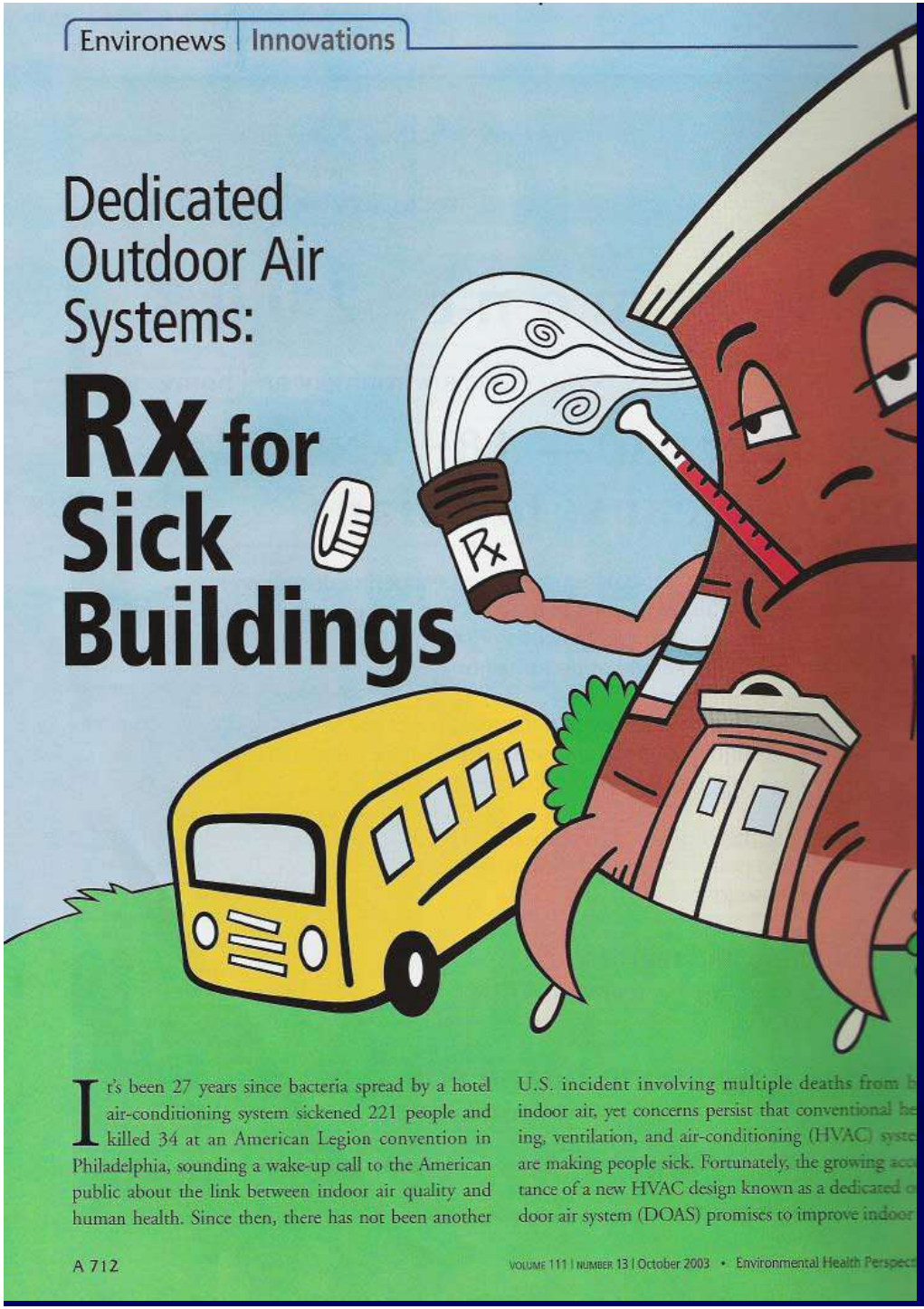


Figure 2.1: Pathways of human exposure.

You are what you eat

- ***Hydroxylapatite***, Ca)5(PO4)3(OH), is the mineral in bone. Actually, many other cations can substitute for calcium within the crystal structure of hydroxylapatite.
- ***Magnesium*** is one possible substitute for calcium. That the bones can be a source of magnesium may become important when ingestion levels of the element are inadequate.
- ***Strontium*** is another calcium substitute.
- One of the most thoroughly researched ions that partition into apatite is fluorine high water concentrations were shown in the early decades of the 20th century to be responsible for mottled teeth. Typical symptoms of fluorosis include dental fluorosis, or mottling of tooth enamel, and various forms of skeletal fluorosis including, osteosclerosis, limited movement of the joints, and outward manifestations such as knock-knees, bowlegs and spinal curvature. Fluorosis combined with nutritional deficiencies in children can result in severe bone deformation
- Human nutritional requirements include calcium, phosphorous, magnesium and fluorine if we wish to maintain a healthy, mineralized skeletal and dental system. All nutrients come from Earth's rocks and minerals, the bailiwick of geologists.



Nine Indoor Air Hazards

1-Moisture and biologicals (such as molds, mildew and dust mites).
2-Combustion products, including carbon monoxide.
3-Formaldehyde.
4-Radon.
5-Household products and furnishings.
6-Asbestos.
7-Particulates.
8-Remodeling byproducts.
9-Environmental tobacco smoke.

Our Natural Environment and Health

"High levels of arsenic in drinking water has caused severe health problems in many countries. In West Bengal alone, over 50 million people are at risk of developing arsenic poisoning" ***Lancet***, 2002

Important to medical geology because:

Significantly more quantitative than estimation of risk and more directly controlled by environmental and geological factors, intervention possible!

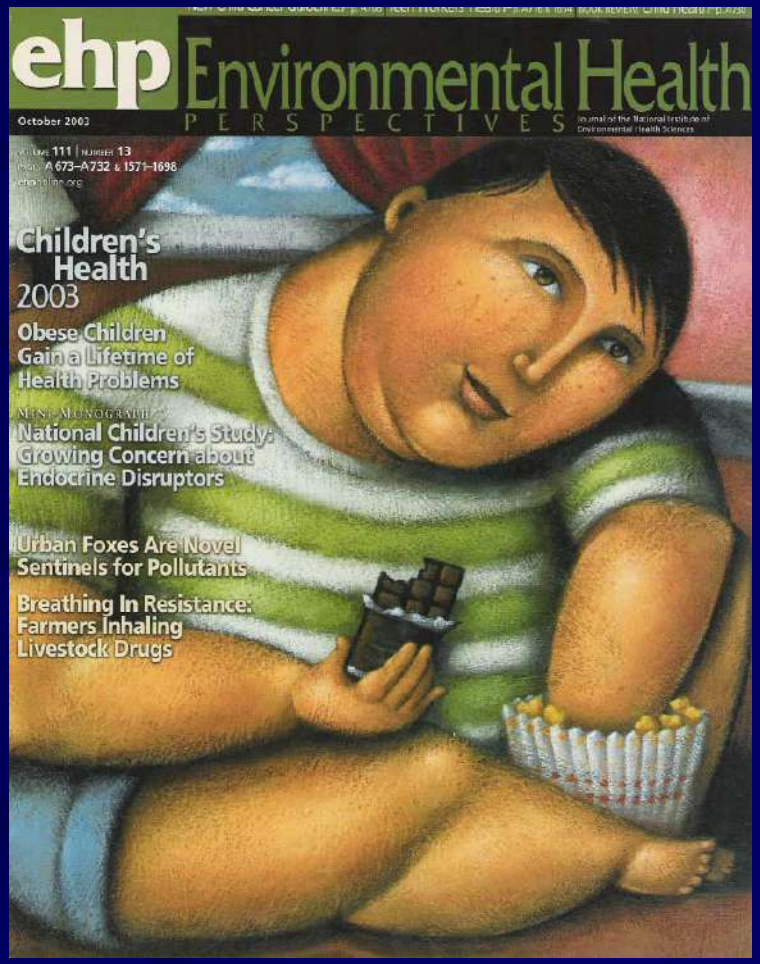
Where You Live ?

Soil You Eat ?

Water You Drink ?

Children's Environmental Health

- Deficiencies
  - Iodide, zinc
- Toxic effects
  - Lead, asbestosis, zinc
- Side effects
  - Directs effect
    - Dust, copper, ionized and non ionized-radiation
  - Indirect effect
    - Obesity



Environmental pollutants and disease in American Children: Estimates of morbidity, mortality and costs for lead poisining, asthma, cancer and developmental disabilities.

Landrigan PJ et al. Environ Health Perspect 110:721-28,2002

- *100% lead poisoning, 30% asthma, 5% cancer, 10% neurobehavioral disorders*

- *43.4 billion USD lead poisoning, 2 billion USD for asthma, 0.3 billion USD for childhood cancer, 9.2 billion USD for neurobehavioral disorders, total annual cost 54.9 billion USD*

Medical Geology

A Working Definition

Medical Geology is **defined as the science dealing with the relationship between geological materials and geologic processes and their impacts on health problems in man and animals.**

The scope and range of Medical Geology include:

- **identifying and characterizing natural sources of harmful materials in the environment;**
- **learning how to predict the movement and alteration of chemical, infectious, and other disease-causing agents;**
- **and understanding how people may be exposed to such materials.**

Our Natural Environment and Health

Lake Nyos, Cameroon Environmental Tragedy

Groundwater arsenic calamity in Bangladesh

Ratan Kr. Dhar, Bhajan Kr. Biswas, Gautam Samanta, Badal Kr. Mandal, D. Chakraborti†, Shibtosh Roy*, Abu Jafar*, Ariful Islam*, Gulshan Ara*, Saiful Kabir*, A. Wadud Khan, S. Akther Ahmed** and S. Abdul Hadi****

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CURRENT SCIENCE, Vol. 73, No. 1, July 10, 1997, pp. 48-59.

Bangladesh victim of world's worst mass poisoning

Arsenic-tainted water blamed for sickness, death

By Paul Salopek
Chicago Tribune

NUWAPARA, Bangladesh — When the mysterious sores first appeared on Anil Chadra Das' work-toughened hands, the grizzled rice farmer, long hardened against the aches and pains of life in rural Bangladesh, just ignored them.

But the lesions didn't go away. Instead, the small purplish scabs

lard Chappell, an environmental expert at the University of Colorado who recently visited the affected areas in India as the director of an international task force on arsenic poisoning. "You just shake your head in amazement at this one."

The cast of characters in the emerging health disaster includes armies of quack doctors who prey on the poisoning victims, knowing

"My parents told me to leave home when I got sick. They said the spirits of our house were displeased," said Howladar.

Experts say the arsenic beneath Bangladesh's fertile river deltas was probably deposited eons ago after washing down from bodies of ore in the Himalayas. As long as the arsenic compounds — called

mained inert.

But with the advent of intensive irrigation in the 1970s, the aquifers have dropped, exposing the poisons to oxygen for the first time.

Once oxidized, arsenic sulfides become water-soluble.

And like tea seeping from a bag, they percolate from subsoils into dropping water tables with every monsoon flood.

Or so the leading theory goes.

"Nobody knows, exactly," says

who has followed arsenic poisoning outbreaks in Taiwan, Chile, Mexico and the western United States. Most of those incidents have sickened a few thousand people.

One reason the world's worst arsenic epidemic has been so muted, Gibb said, is that — contrary to its sinister, suicide-capsule reputation — arsenic poisoning can be undramatic, even stealthy.

Even wells fouled with 200 times the World Health Organization's

have been found near Suma's village, will not kill outright.

Instead, a buildup of the lethal chemical over months or years causes a wide array of increasingly debilitating ailments, from lesions on the hands and feet to organ cancers, neural disorders, deafness and, possibly, even diabetes.

"Just wait. You'll start seeing patterns of cancers pop up in this region in a few years," said Gibb. "This is a major tragedy exactly

THE DENVER POST, Thursday, January 16, 1997

Definitions

Bioavailability - the fraction of an administered dose that reaches the central (blood) compartment from the gastrointestinal tract.

Bioaccessibility - the fraction that is soluble in the gastrointestinal environment and is available for absorption.