B I O A C C U M U L A T I O N

OF TOXIC SUBSTANCES

XENOBIOTICS released to the environment can be taken up by organisms

BIOACCUMULATION produces higher concentration of a chemical in an organism than in its immediate environment, including food

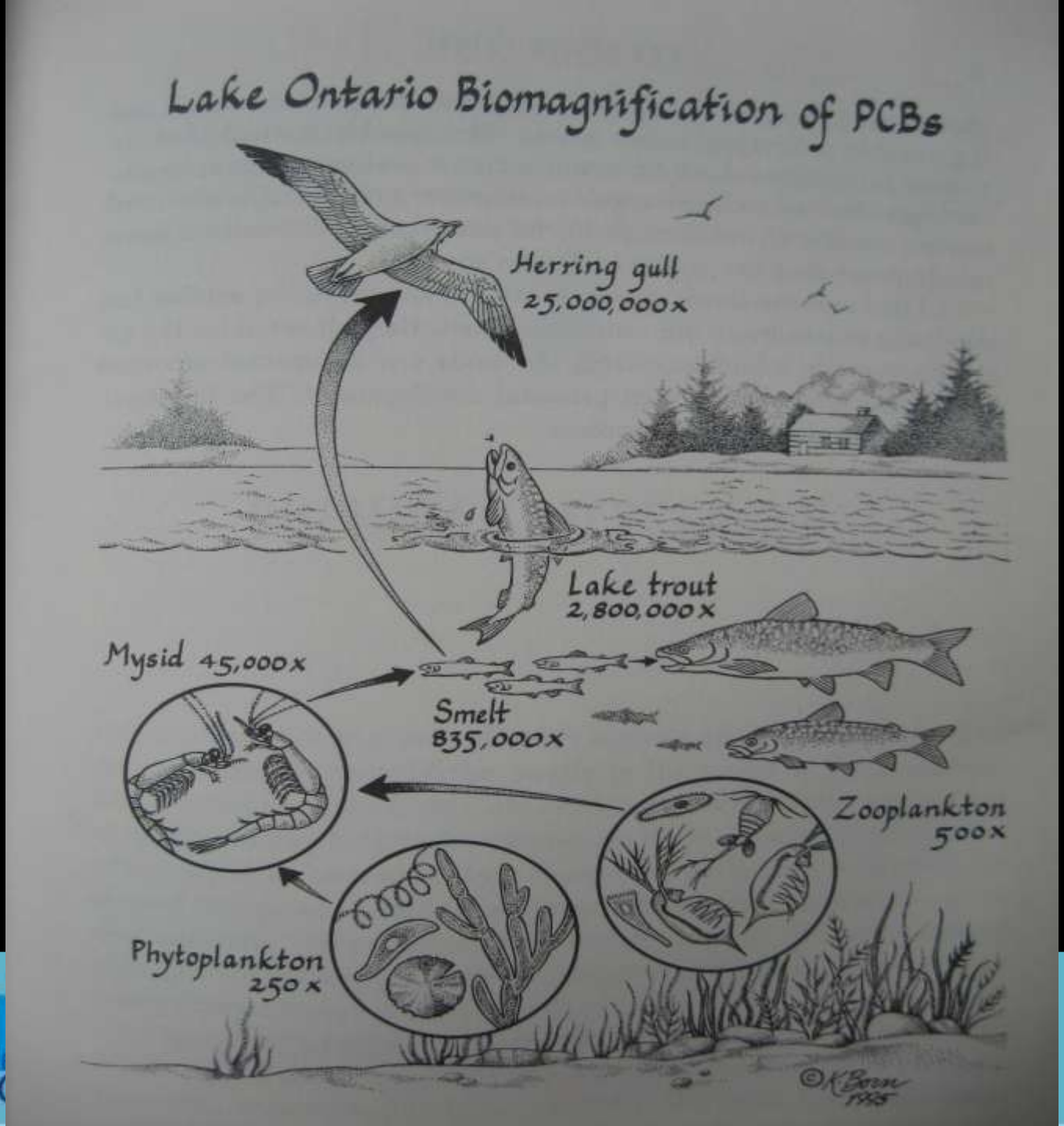
BIOCONCENTRATION
A process which leads to higher concentration of Xenobiotics in the organisms than in the environment

BIOMAGNIFICATION

A successive increase of bioaccumulation along the food chain – occurs when food is the major source of bioaccumulation

BIOACCUMULATION

- different routes (*via* air, water, solid & sediment)
- depend on environmental & physiological factors


Lake Ontario Biomagnification of PCBs
Herring gull
25,000,000x
Lake trout
2,800,000x
Mysid 45,000x
Smelt
835,000x
Zooplankton
500x
Phytoplankton
250x
©K Boon
1985

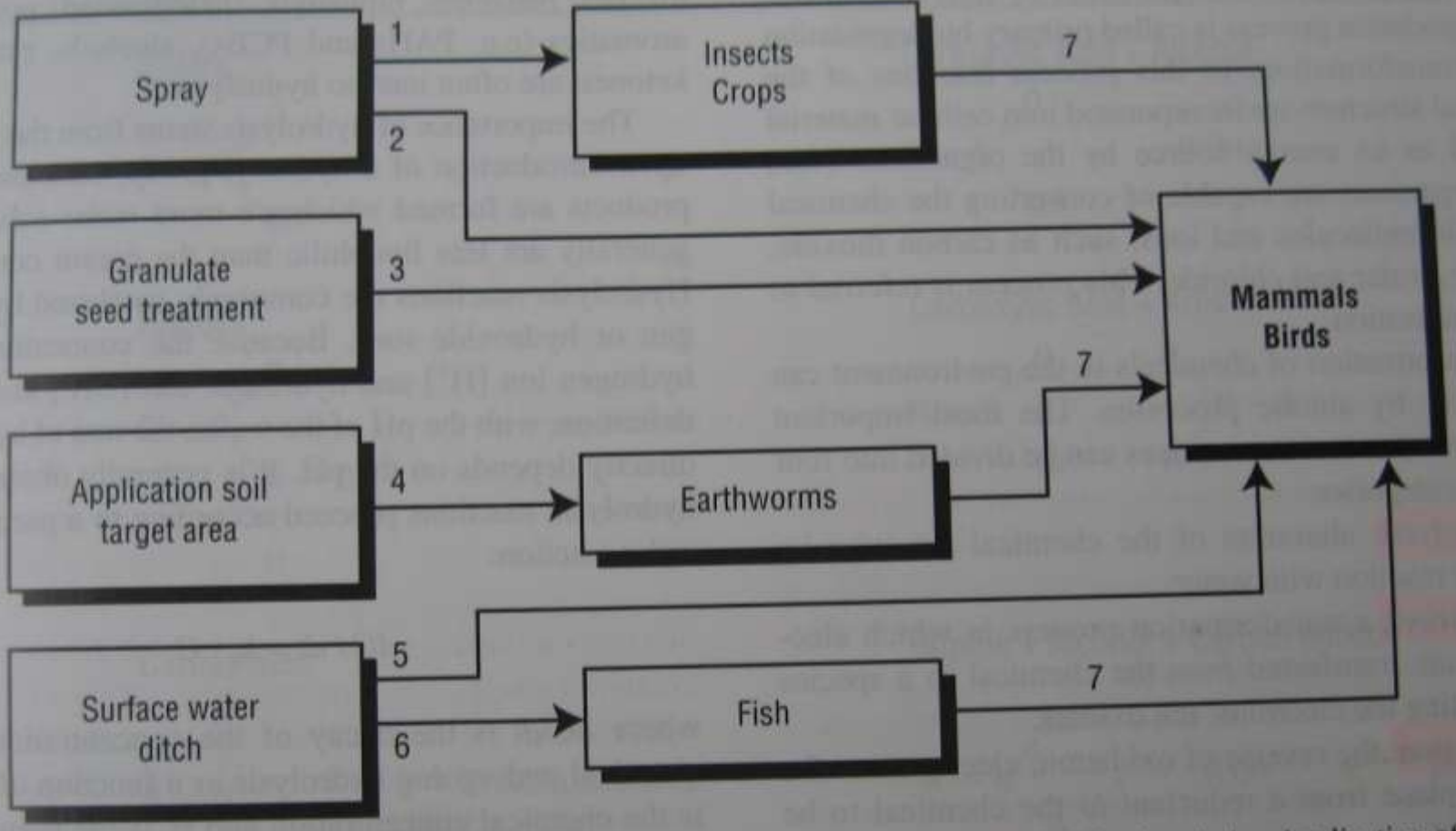


Figure 3.28. Food as a major source of contaminants for mammals and birds in a simplified food web. 1 = Application of spray, 2 = Drinking from leaves/crops, 3 = Ingestion of granules/treated seeds, 4 = Bioconcentration soil-worm, 5 = Drinking from surface water, 6 = Bioconcentration water-fish, 7 = Consumption. From USES [44]. With permission.

FUGACITY OF A CHEMICAL

The ratio of concentration to storage capacity

WATER

- Low concentration
- small storage capacity (solubility)

→ HIGH FUGACITY

ORGANISM

- Low ~> high concentration
- high storage capacity (per unit of volume)

→ LOW FUGACITY

CHEMICAL
FLUX

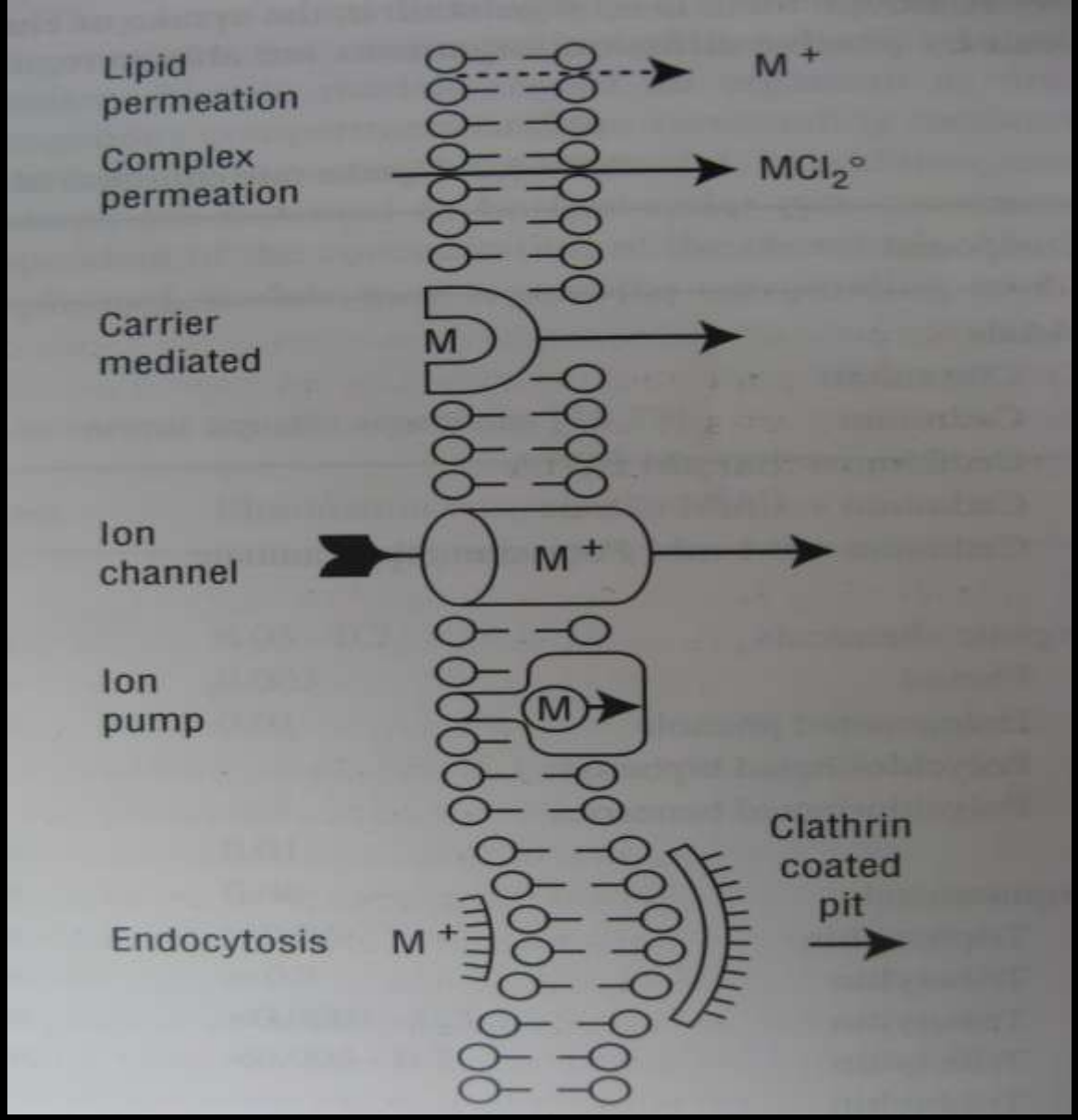
HIGH FUGACITY  LOW FUGACITY

ABSORPTION, DISTRIBUTION, AND EXCRETION OF TOXICANTS

Karl K. Rozman and Curtis D. Klaassen

UPTAKE PROCESSES

- Several processes involving the passage of compounds across a biological membranes, mediated by a carrier or as a single solute
- Passive diffusion
- Fugacity
- Complex permeation
  - by carrier mediated processes
  - by ion channel
  - by ATPase



UPTAKE PROCESSES

Example:

Cadmium (Cd^{2+}) may be taken up by Ca^{2+}-ATPases

or as

Cadmium Xanthate complex (in fish)

FACTORS AFFECTING BIOCONCENTRATION

1. MOLECULAR SIZE
2. MOLECULAR CHARGE
3. Chemical SPECIATION: Cadmium [$Cd\ Cl_2$, $Cd\ NO_3$]
4. SURFACE/VOLUME RATIO
   ~> smaller organisms take up and eliminate chemicals faster than large organisms
5. MORPHOLOGY, PHYSIOLOGY (e.g. filter feeder)
6. BIOTRANSFORMATION
   ~> degrades the chemical to more polar products catalized by enzymes

Chemical SPECIATION: Cadmium [$Cd\ Cl_2$, $Cd\ NO_3$]

Cr^{3+} less toxic

Cr^{6+} highly toxic

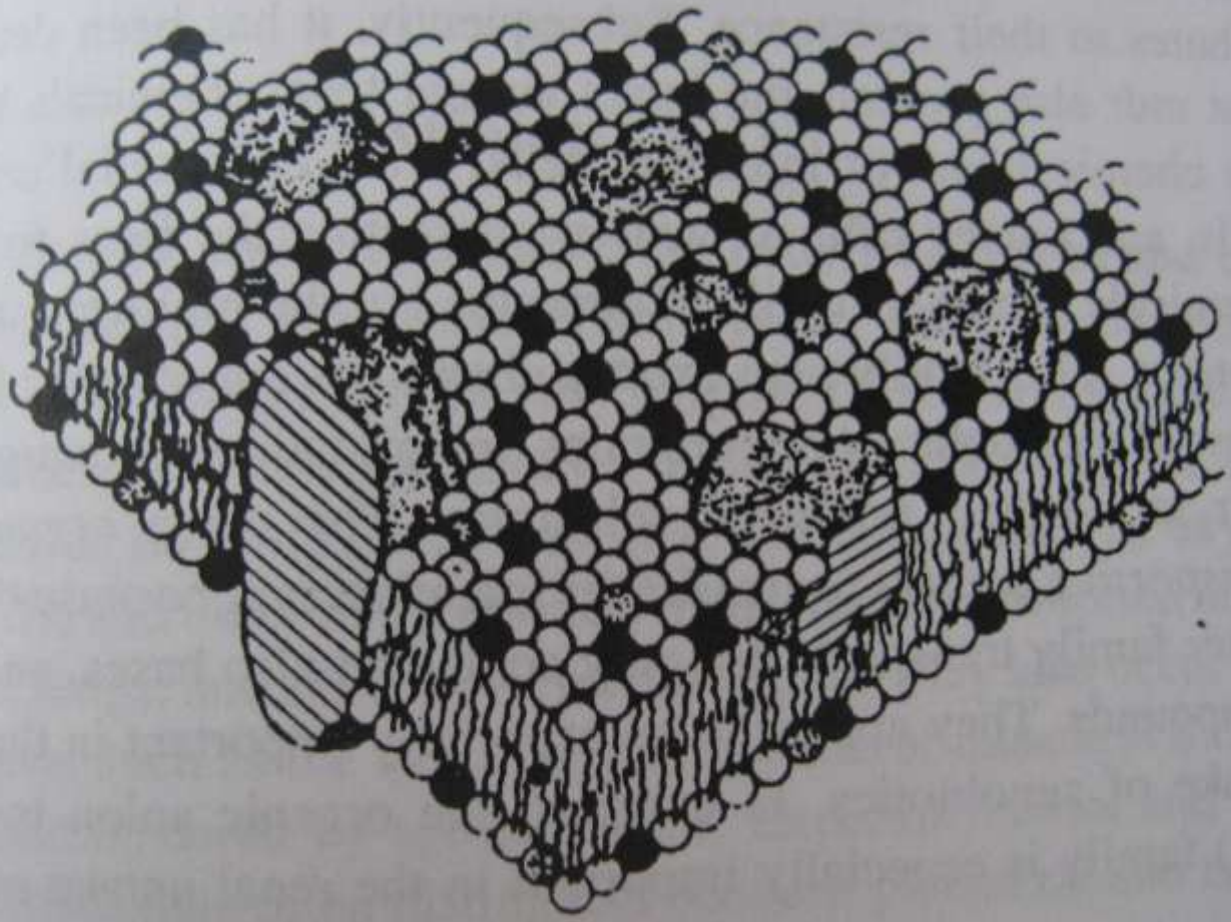


Figure 5-2. Schematic model of a biological membrane.

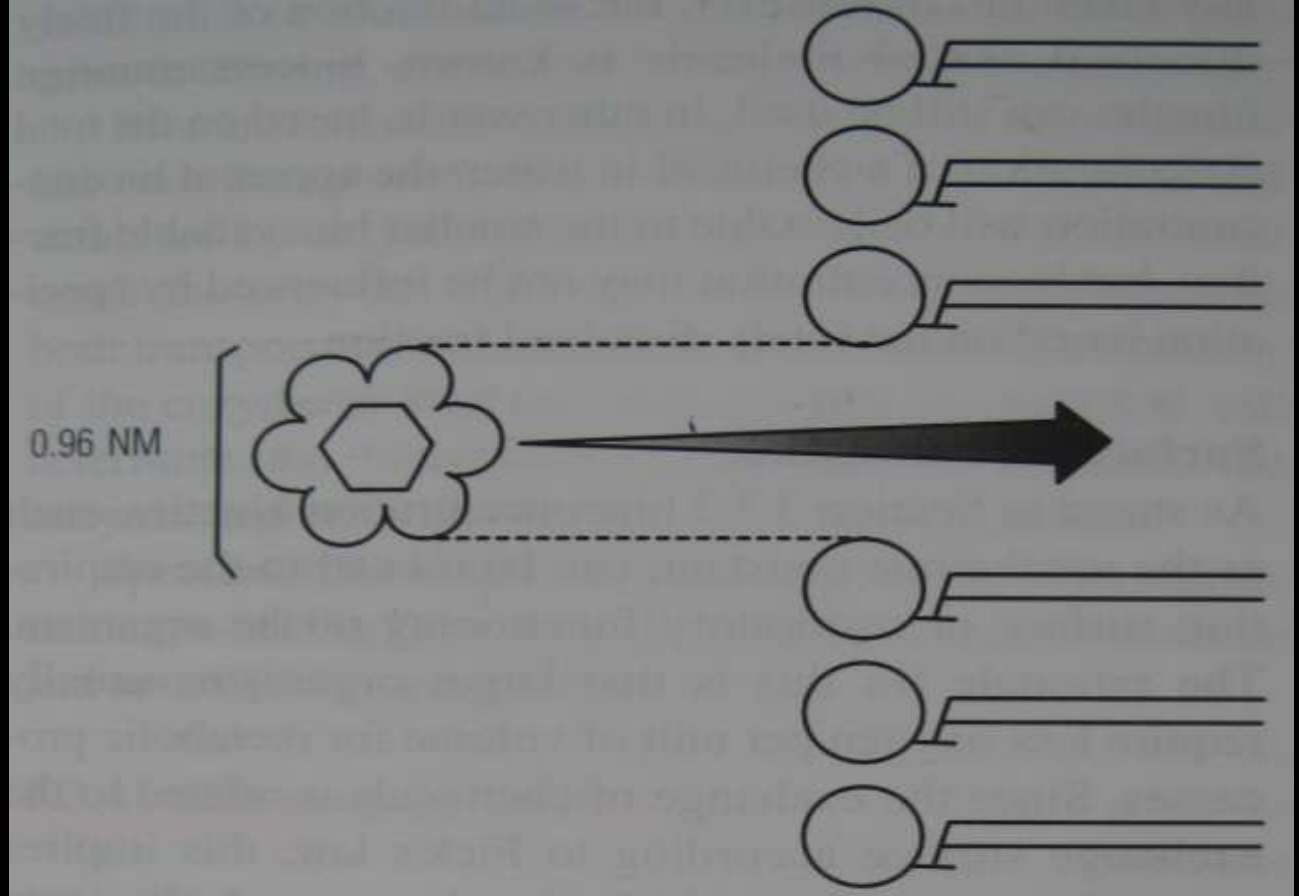


Figure 3.20. Diagram showing the transfer of a hydrophobic molecule across the polar heads of a bilipid membrane in relation to the effective cross-section of the membrane's cavity for neutral organic chemicals. Reprinted from [25]. With kind permission from Elsevier Science Ltd.

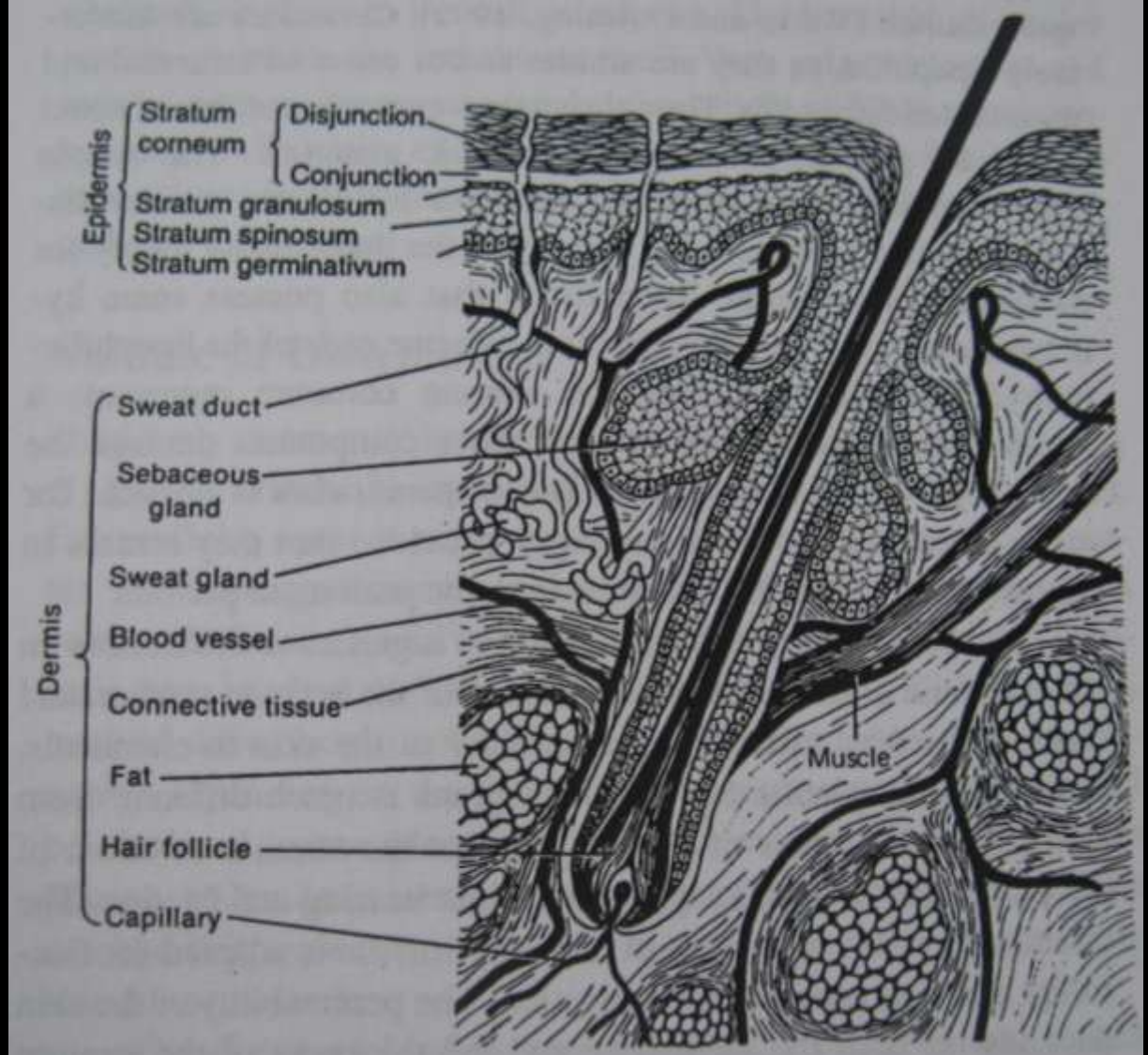
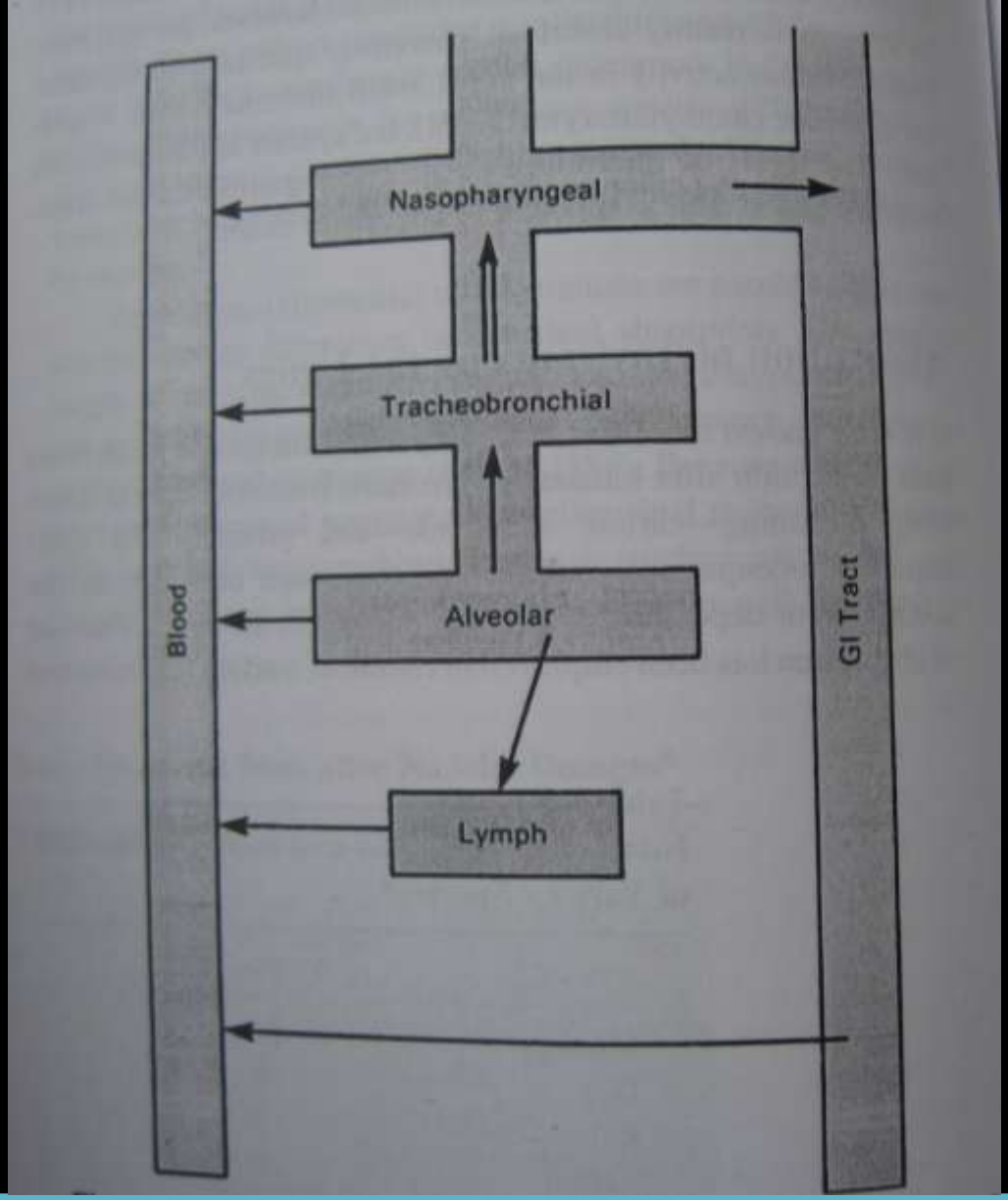


Figure 5-5. Diagram of a cross section of human skin.



Schematic Diagram of the absorption and translocation of chemicals by lungs

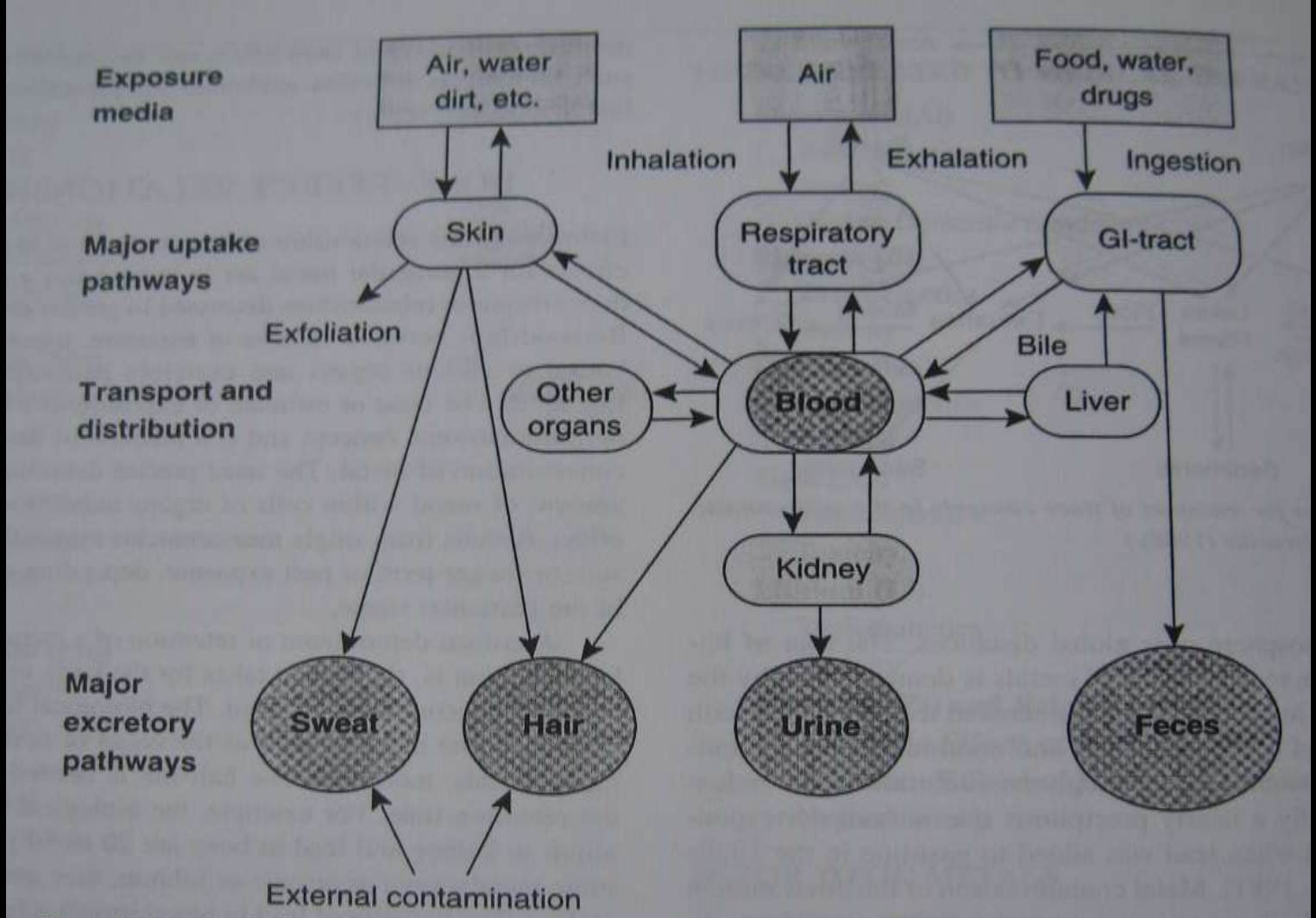


Figure 23-2. Metabolism after exposure to metals via skin absorption, inhalation and ingestion.

The arrows indicate how the metals are transported and distributed. Tissues that are particularly useful for biological monitoring are identified in shaded areas. [From Elinder et al. (1994), with permission.]

ORGANISMS (BIOACCUMULATION)

- METALS bind to protein (metallothionein)
- ORGANIC CHEMICALS are stored in lipids
- ORGANOMETALS are stored in either lipids or protein

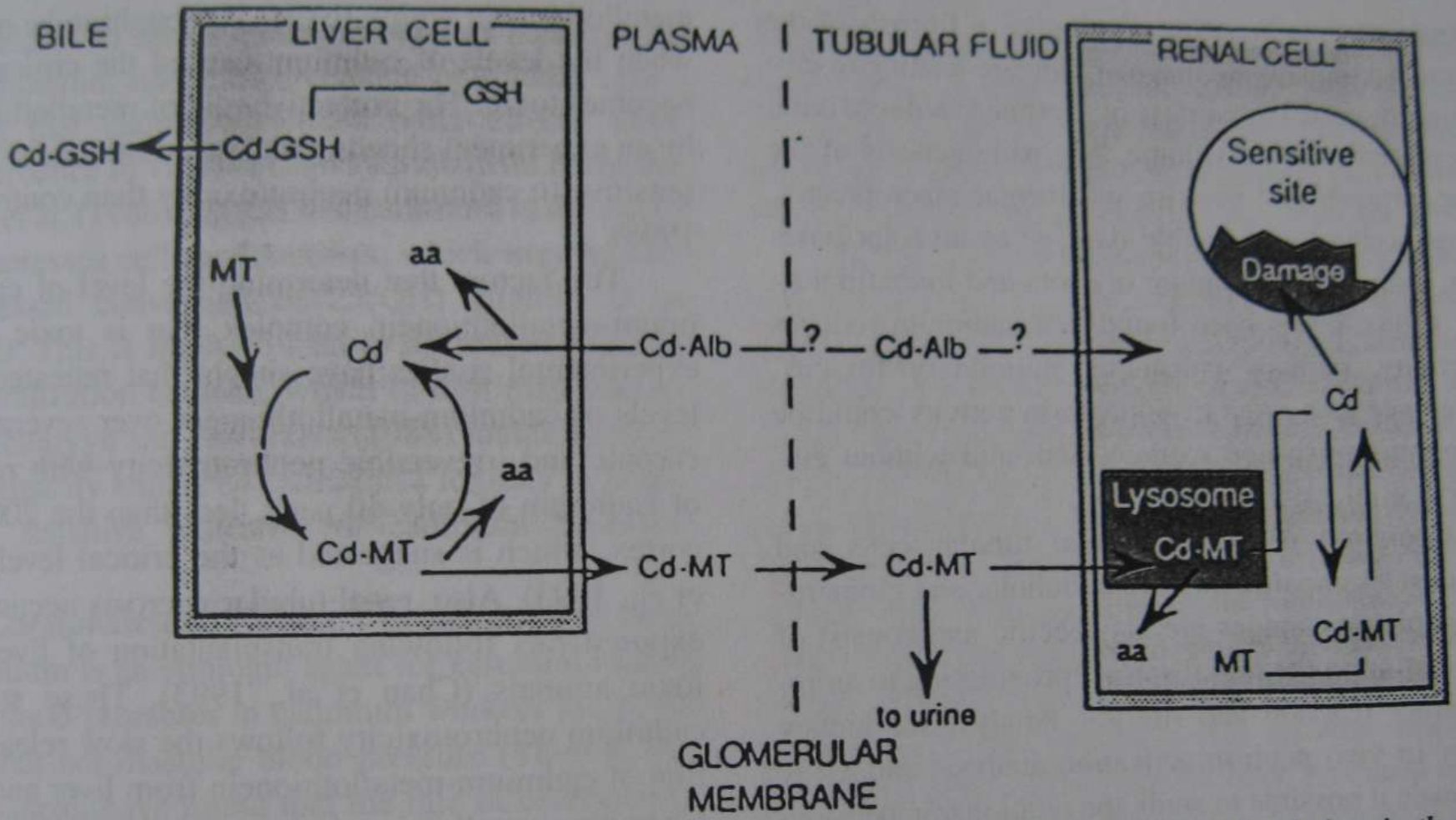


Figure 23-3. A schematic representation of the role of metallothionein in the disposition of cadmium in the liver and kidney. [Adapted from Jarup et al. (1998).]

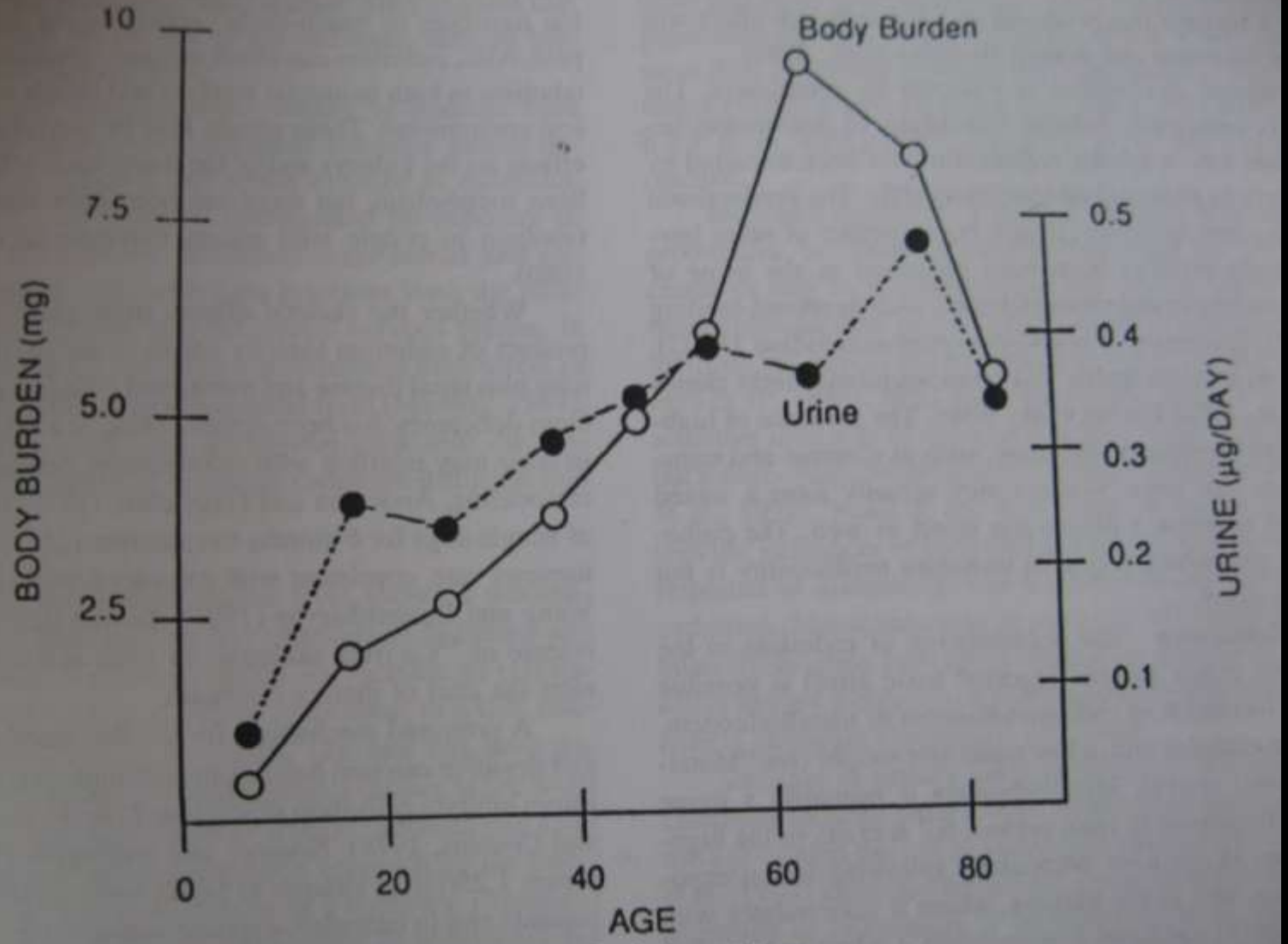


Figure 23-4. Illustration of the accumulation of cadmium with age.

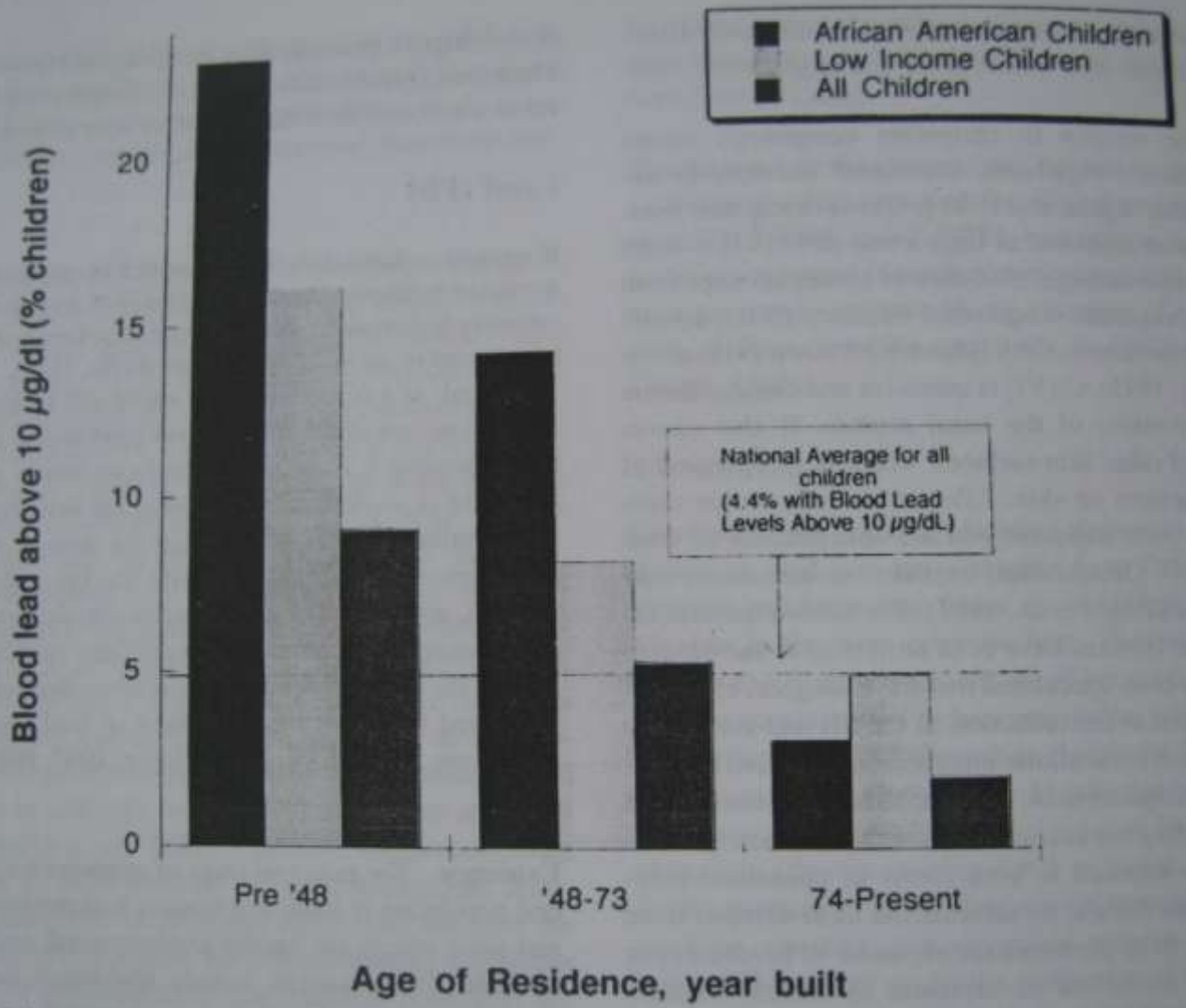


Figure 23-5. National blood lead levels. National Health and Nutrition Examination Survey. Phase 2, 1991–1994. [Adapted from CDC (2000).]

ELIMINATION

- Passive & active mechanisms
- Hydrophobic chemicals: passive diffusion (water, faeces)
- Growth
- Biotransformation

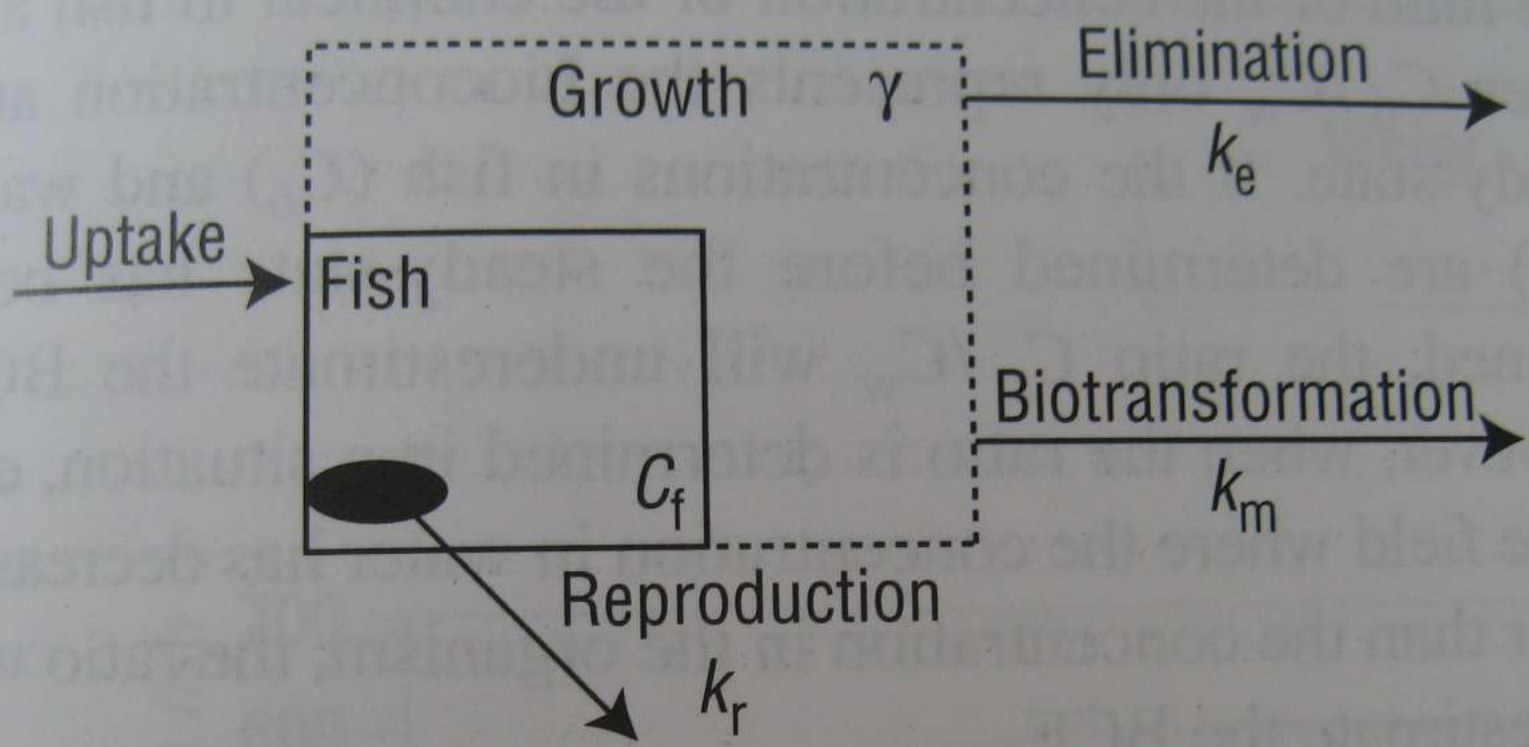
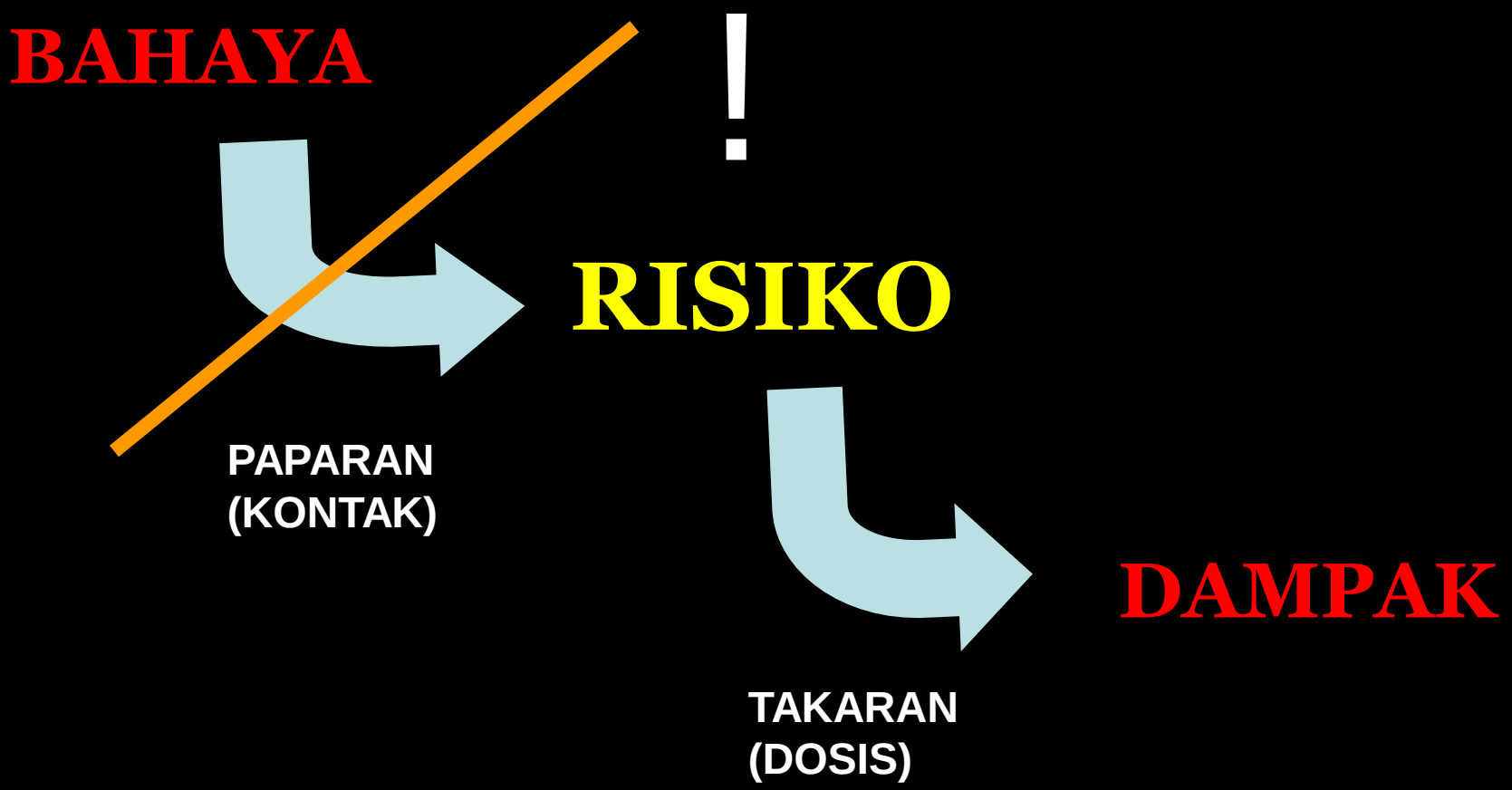


Figure 3.15. Different processes which reduce the concentration of xenobiotic contaminants in an organism (C_f): physicochemical elimination (k_e), biotransformation (k_m), growth (γ) and reproduction (k_r). From [30]. With permission.


BAHAYA
!
RISIKO
PAPARAN
(KONTAK)
DAMPAK
TAKARAN
(DOSIS)

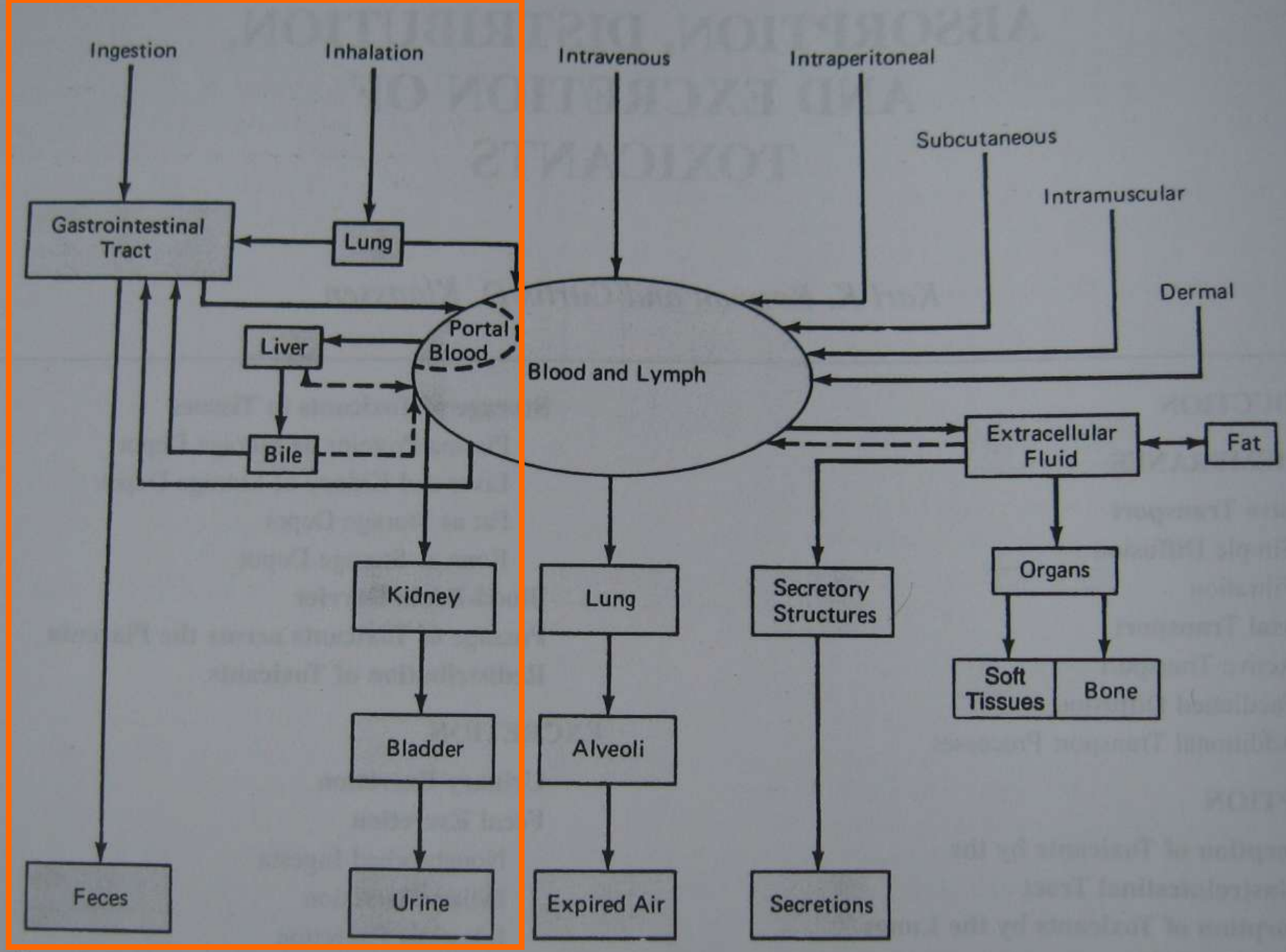


Figure 5-1. Routes of absorption, distribution, and excretion of toxicants in the body.