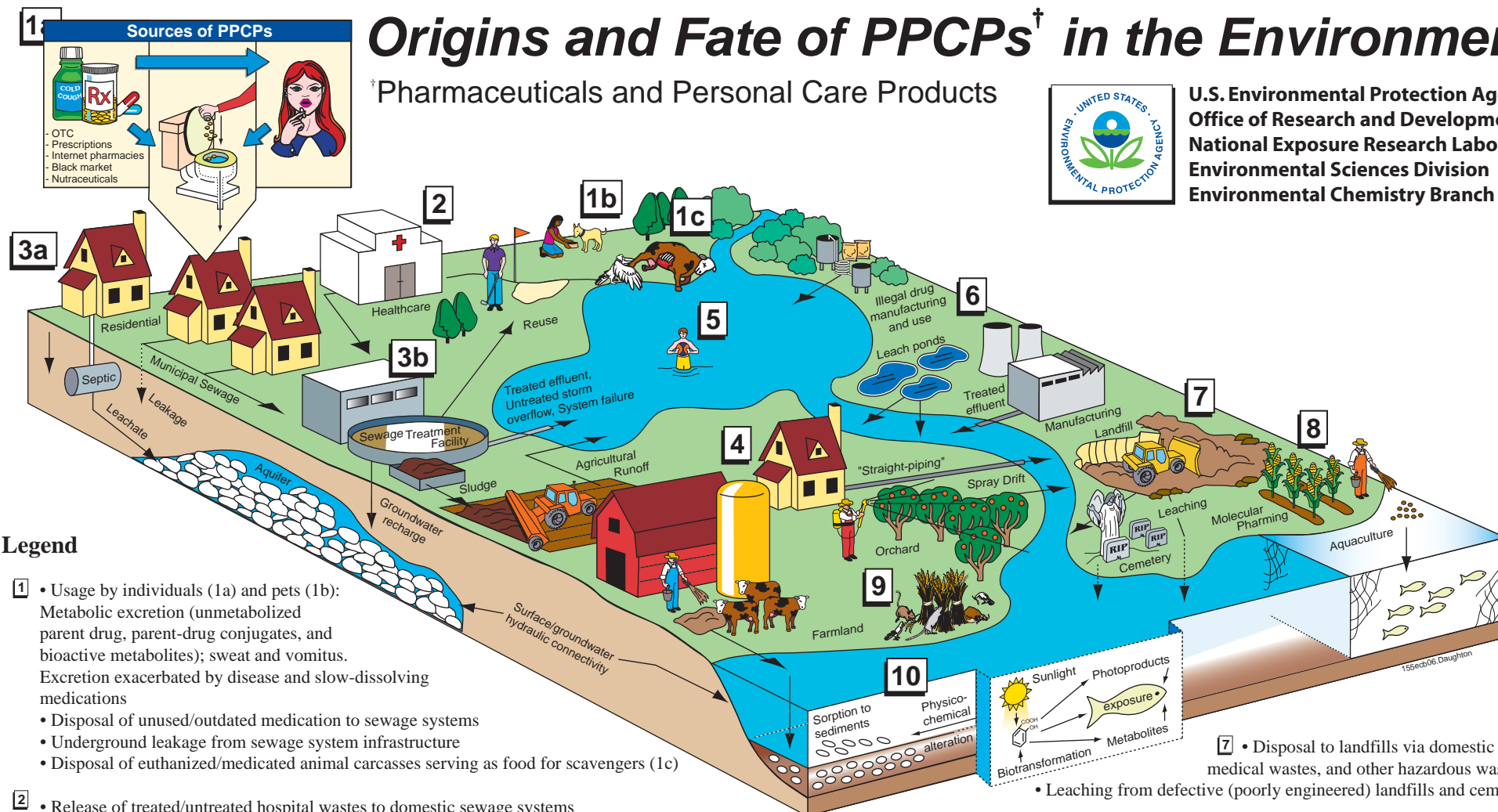


# Origins and Fate of PPCPs<sup>†</sup> in the Environment

<sup>†</sup>Pharmaceuticals and Personal Care Products



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National Exposure Research Laboratory  
Environmental Sciences Division  
Environmental Chemistry Branch



## Legend

- 1** • Use by individuals (1a) and pets (1b): Metabolic excretion (unmetabolized parent drug, parent-drug conjugates, and bioactive metabolites); sweat and vomitus. Excretion exacerbated by disease and slow-dissolving medications
  - Disposal of unused/outdated medication to sewage systems
  - Underground leakage from sewage system infrastructure
  - Disposal of euthanized/medicated animal carcasses serving as food for scavengers (1c)
- 2** • Release of treated/untreated hospital wastes to domestic sewage systems (weighted toward acutely toxic drugs and diagnostic agents, as opposed to long-term medications); also disposal by pharmacies, physicians, humanitarian drug surplus
- 3** • Release to private septic/leach fields (3a)
  - Treated effluent from domestic sewage treatment plants discharged to surface waters, re-injected into aquifers (recharge), recycled/reused (irrigation or domestic uses) (3b)
  - Overflow of untreated sewage from storm events and system failures directly to surface waters (3b)
- 4** • Transfer of sewage solids ("biosolids") to land (e.g., soil amendment/fertilization)
  - "Straight-piping" from homes (untreated sewage discharged directly to surface waters)
  - Release from agriculture: spray drift from tree crops (e.g., antibiotics)
  - Dung from medicated domestic animals (e.g., feed) - CAFOs (confined animal feeding operations)
- 5** • Direct release to open waters via washing/bathing/swimming
- 6** • Discharge of regulated/controlled industrial manufacturing waste streams
  - Disposal/release from clandestine drug labs and illicit drug usage
- 7** • Disposal to landfills via domestic refuse, medical wastes, and other hazardous wastes
  - Leaching from defective (poorly engineered) landfills and cemeteries
- 8** • Release to open waters from aquaculture (medicated feed and resulting excreta)
  - Future potential for release from molecular pharming (production of therapeutics in crops)
- 9** • Release of drugs that serve double duty as pest control agents:
  - examples: 4-aminopyridine, experimental multiple sclerosis drug → used as avicide; warfarin, anticoagulant → rat poison; azacholesterol, antilipidemics → avian/rodent reproductive inhibitors; certain antibiotics → used for orchard pathogens; acetaminophen, analgesic → brown tree snake control; caffeine, stimulant → *coqui* frog control
- 10** Ultimate environmental transport/fate:
  - most PPCPs eventually transported from terrestrial domain to aqueous domain
  - phototransformation (both direct and indirect reactions via UV light)
  - physicochemical alteration, degradation, and ultimate mineralization
  - volatilization (mainly certain anesthetics, fragrances)
  - some uptake by plants
  - respirable particulates containing sorbed drugs (e.g., medicated-feed dusts)