



Lecture Objectives

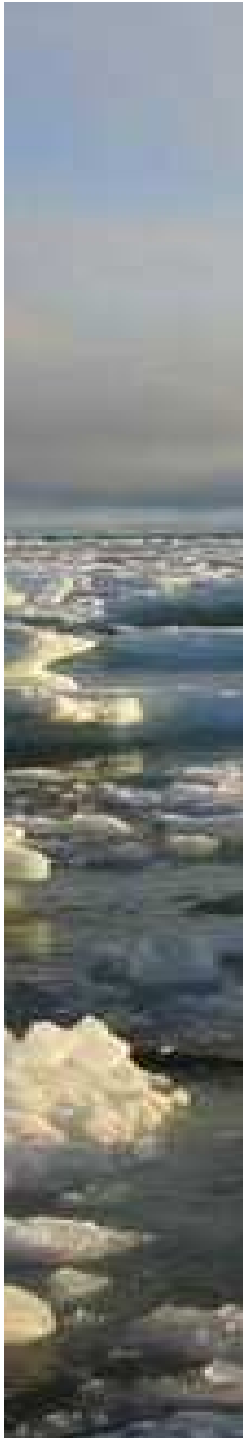
Overall Goal: How do pollutants accumulate in the Arctic?

Specifically:

- Physical characteristics of the Arctic environment
- Transport Pathways – Atmospheric & Oceanic
- Arctic food web
- Chemical properties that result in Arctic accumulation

Arctic Contamination: Background

- In 1970, chlorinated pesticides (ie-DDT) and PCBs were detected in ringed seal blubber from Canadian Arctic
- In late 1980s, breast milk from Inuit in northern Quebec contained contaminants levels up to 10x higher than southern Canada
- Very few industrial sources of these contaminants in the Arctic
- Scientific Puzzle: **How were these pollutants accumulating in the Arctic?**



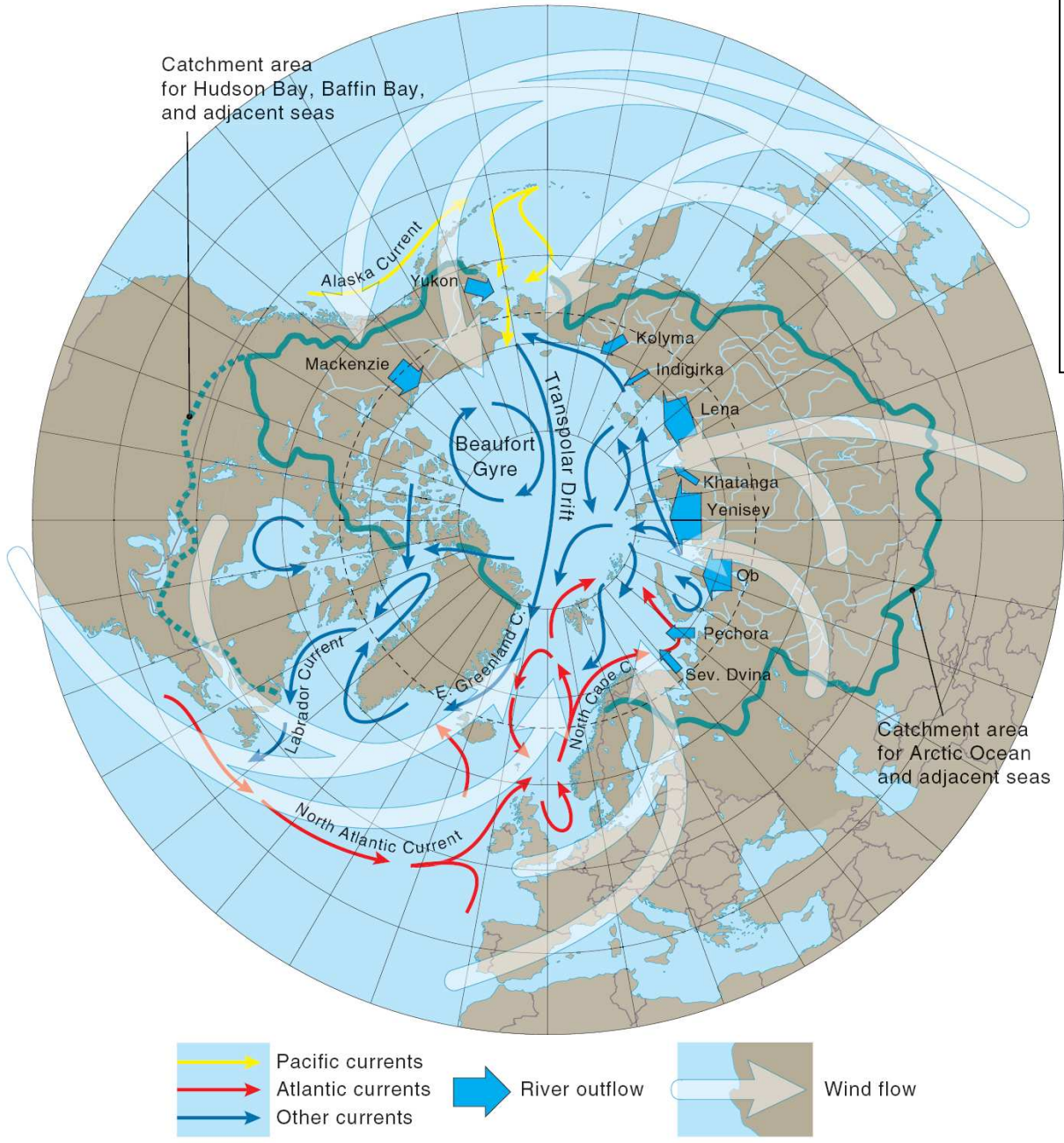


Why study the Arctic?

- Ethical Concerns:
 - Arctic environment is contaminated with chemicals not produced in the region
 - Arctic peoples have not benefited from the production of these chemicals
- Stockholm Convention on Persistent Organic Pollutants (POPs)
 - Criteria defining a POP is Long-Range Transport (LRT)
 - Detection of a pollutant in the Arctic is evidence of LRT

Transport to the Arctic via Atmospheric Currents

- general pattern of movement from southern regions to the Arctic



Source: Arctic Monitoring & Assessment Report



Transport to the Arctic via major Ocean Currents

Transport is *Slow*, ~30 yrs to reach Canadian Arctic Archipelago

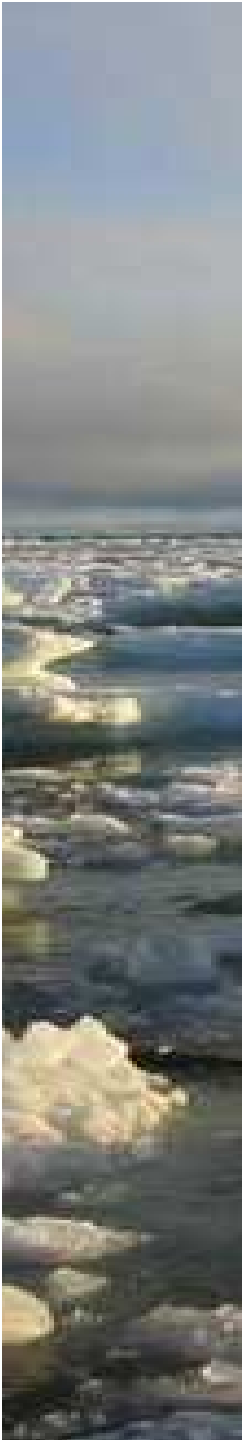
→ Atlantic currents
→ Other currents

Atmospheric Transport

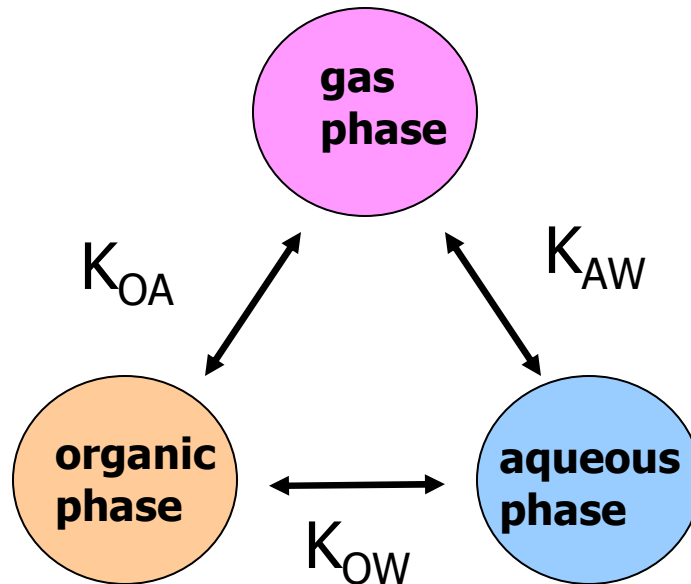


To reach the Arctic,
pollutant must:

- 1) Volatilize to atmosphere from source
- 2) Transported to Arctic (not degraded during travel)
- 3) Must be deposited to Arctic surface (condense)



Atmospheric Transport



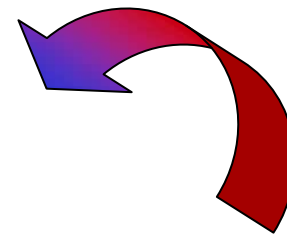
- Chemicals of intermediate volatility (“semi-volatiles”) can cycle (partition) between gas-phase and “condensed phases”; *dependent on temperature*

Atmospheric Transport

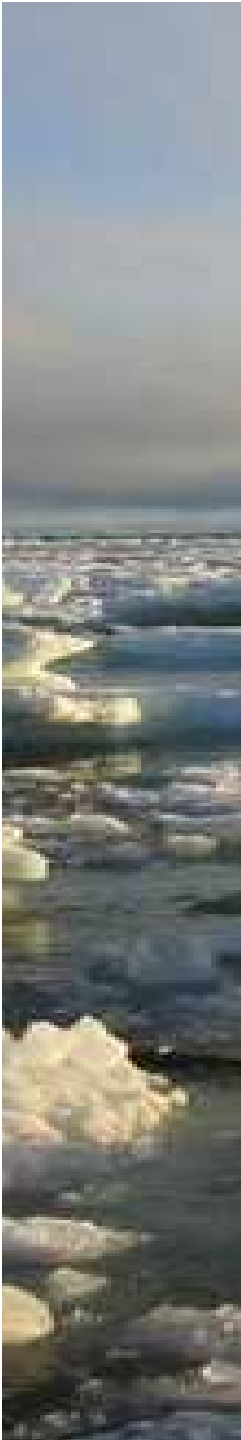
- Temperature dependence may be seasonal, or latitudinal
- Contaminants may migrate in a series of hops, “Grasshopper Effect”
- Transport is contaminant specific, “Global Distillation”



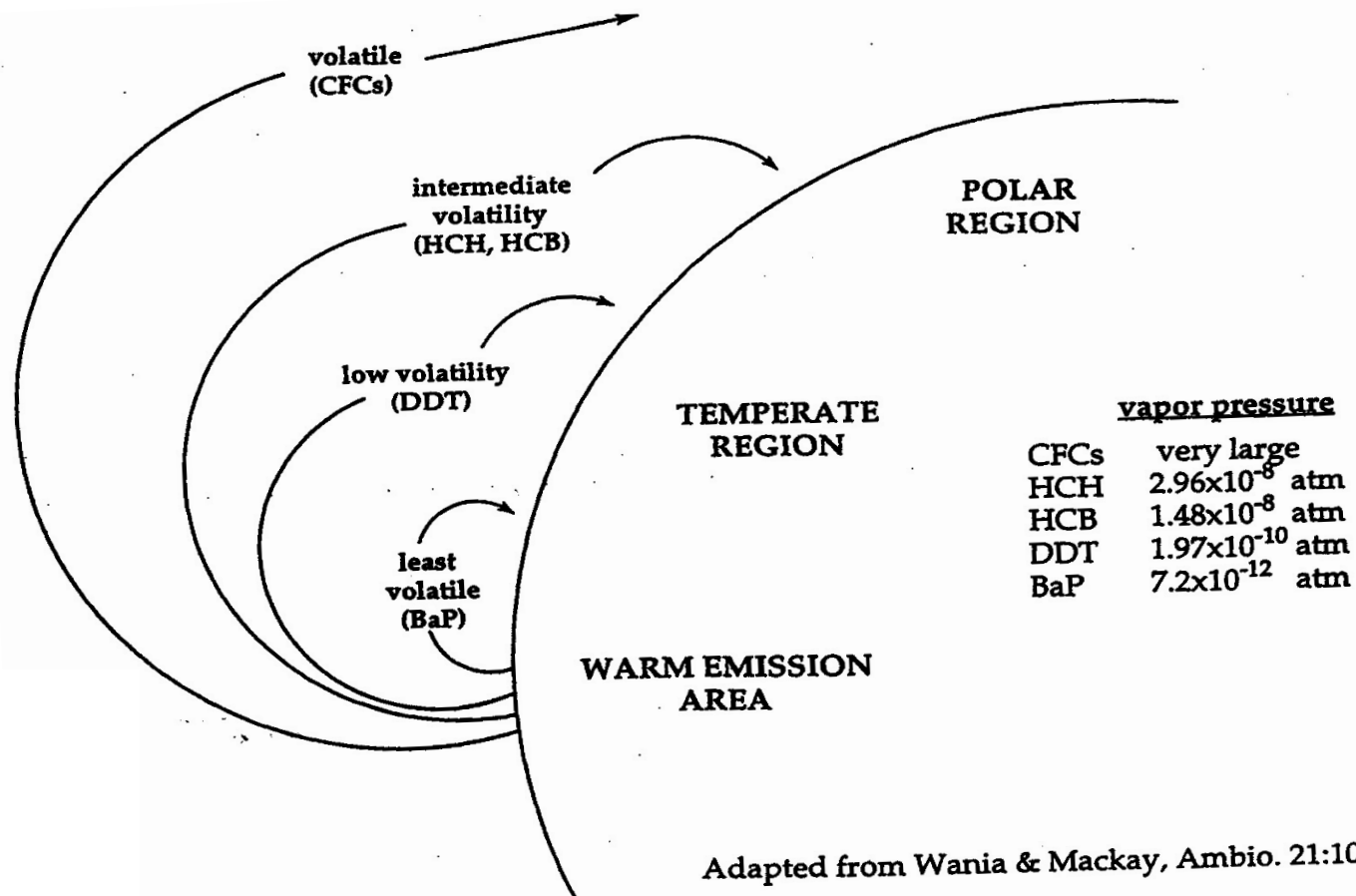
Arctic



Source



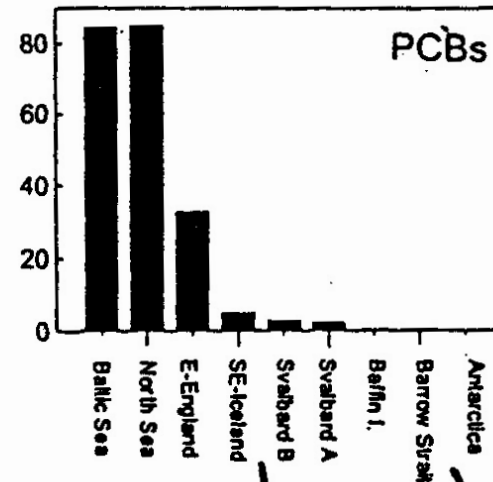
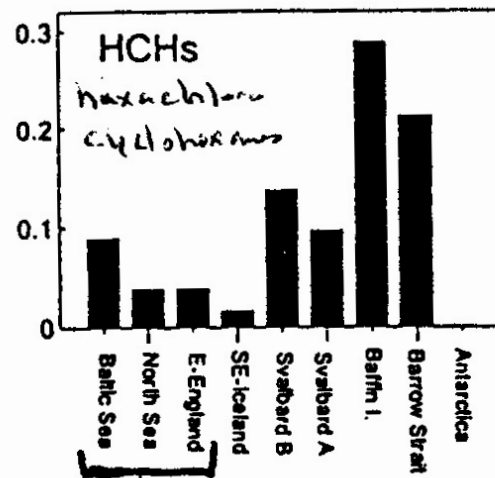
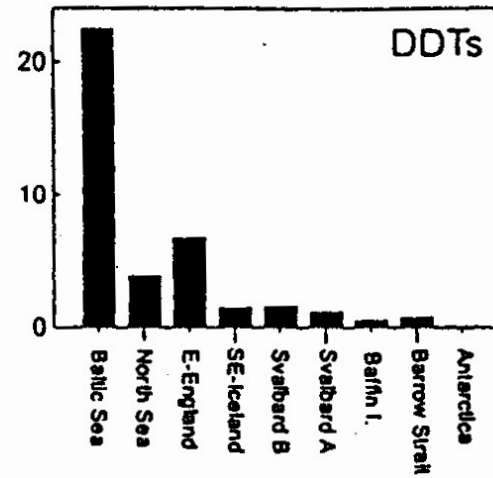
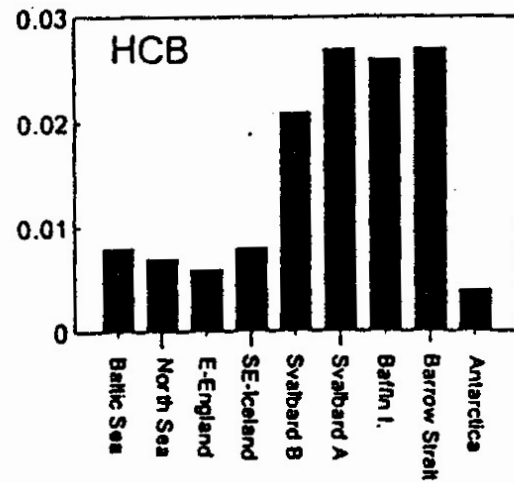
Atmospheric Transport



Adapted from Wania & Mackay, *Ambio*. 21:10-18.

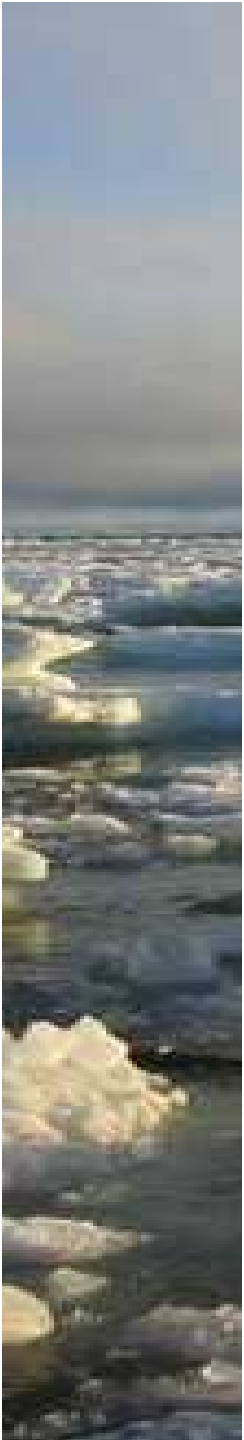


Chlorinated hydrocarbons in ringed seal blubber



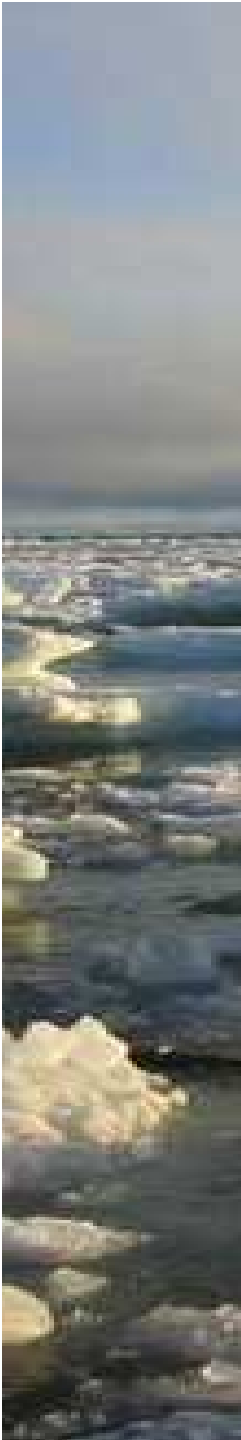
temperate

arctic



Accumulation in Wildlife

- Once transported to Arctic, pollutant must be accumulated into wildlife
- Chemical Property: *hydrophobicity*
 - Hydrophobic contaminants not eliminated from body, partition into fat
 - Results in accumulation within organism



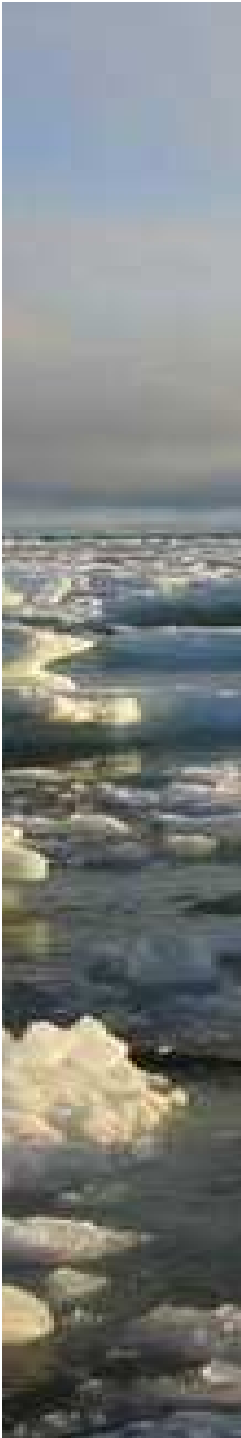


Arctic Ecosystem

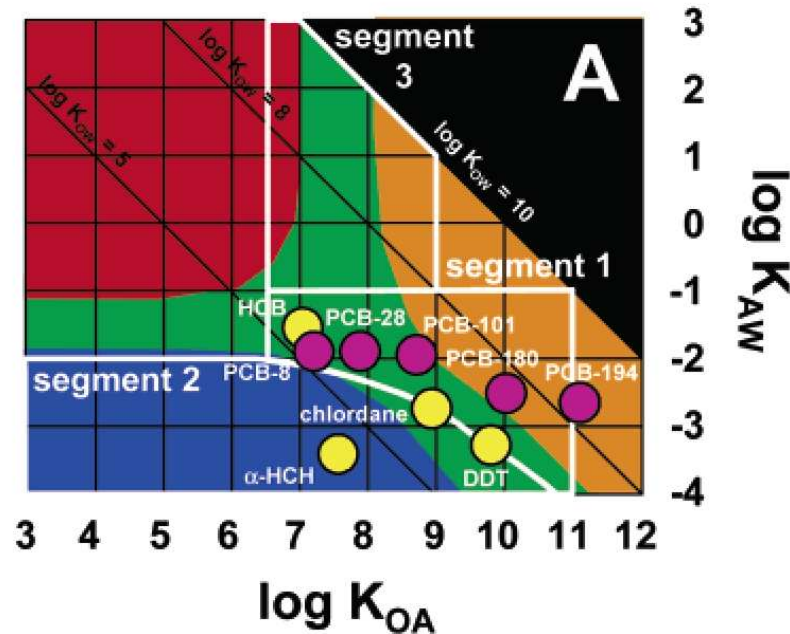
- Arctic characterized by cold temperatures:
 - Degradation reactions and biological metabolism of pollutants slower
 - Arctic animal adaptation; high body fat percentage
 - *high storage capacity* for fat-soluble pollutants
- Arctic characterized by low levels of nutrients
 - Cold-blood animals (ie-fish) are longer lived; increased accumulation of pollutants
 - Higher order carnivores (ie-polar bears) preferentially eat fat of prey (energy rich)
 - Result: **Very efficient transfer of contaminants up the food chain**

Arctic Contamination

- Can we predict which contaminants will accumulate in the Arctic?
 - Chemical must be volatile to undergo atmospheric transport, but must be deposited to the Arctic
 - Must be hydrophobic enough to be bioaccumulative



Predicting Arctic Contamination



- > 2/3 in soils and sediments
- > 2/3 in atmosphere
- > 2/3 in sea and fresh water
- multimedia chemicals

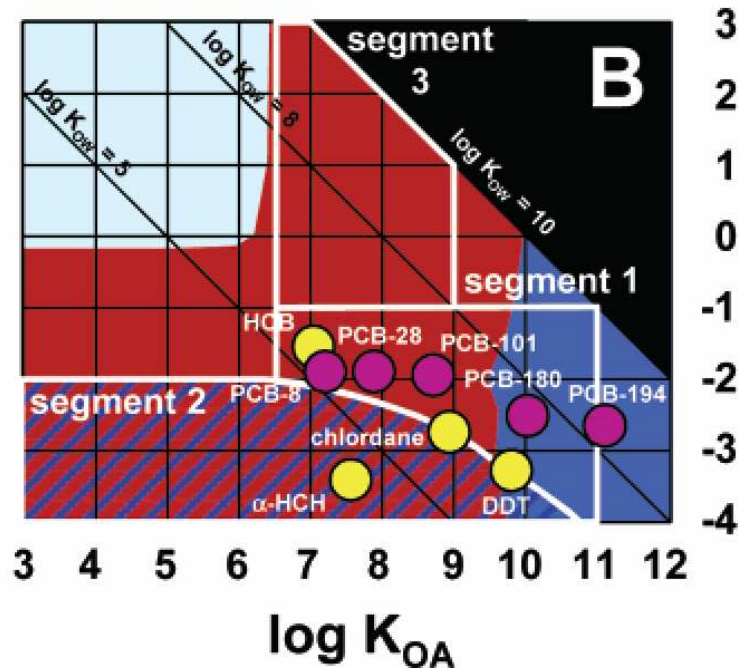
Predicting which environmental phase a contaminant will partition into:

- x-axis represents octanol-air partition coefficient (high K_{OA} = partition from air into condensed organic phase)

- y-axis represents air-water partition coefficient (high K_{AW} = partition from water into air)

Frank Wania, ES&T,
2006, 40, 569-577

Predicting Arctic Contamination



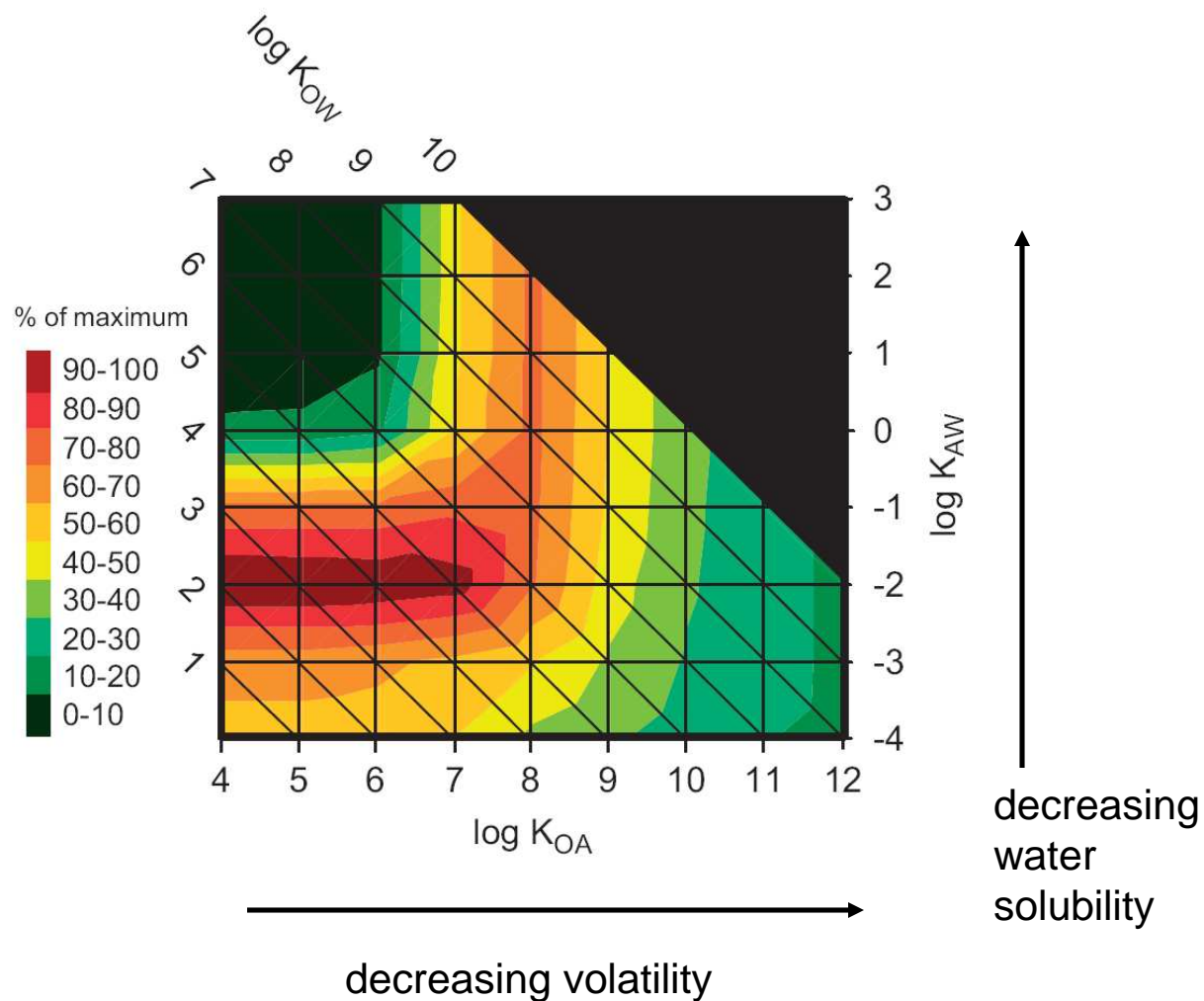
Predicting dominant transport mechanism:

- x-axis represents octanol-air partition coefficient (high K_{OA} = partition from air into condensed organic phase)
- y-axis represents air-water partition coefficient (high K_{AW} = partition from water into air)

Example: low K_{OA} and high K_{AW} , volatile compound will be a "flier"

Frank Wania, ES&T, 2006, 40, 569-577

Predicting Arctic Contamination



Arctic Contamination Potential (ACP), a combination of transport and phase partitioning. High ACP for

- hydrophobic chemicals, intermediate volatility (vertical bar)
- relatively volatile, water soluble chemicals (horizontal bar)

Frank Wania, ES&T,
2003, 37, 1344-1351



Random Quiz

Perfluorinated carboxylates and sulfonates are non-volatile, water soluble organic compounds. Despite these properties, they are found in very high concentrations in Arctic wildlife.

How are they transported to the Arctic?

Random Quiz

Answer: Degradation of precursors that yield perfluorinated carboxylates and sulfonates

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