Uptake and translocation of non-ionised pollutants by plants

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Transfer of organic pollutants from soil to plants
Reading University, September 25/26, 2007

ROTHAMSTED RESEARCH

Pesticides – applied directly to the environment

Industrial pollutants – escape directly or indirectly

Environmental behaviour of organic compounds influenced by physicochemical properties

- sorption to soil
- movement through soil
- bioaccumulation in organisms
- uptake and movement in plants
- atmospheric transport

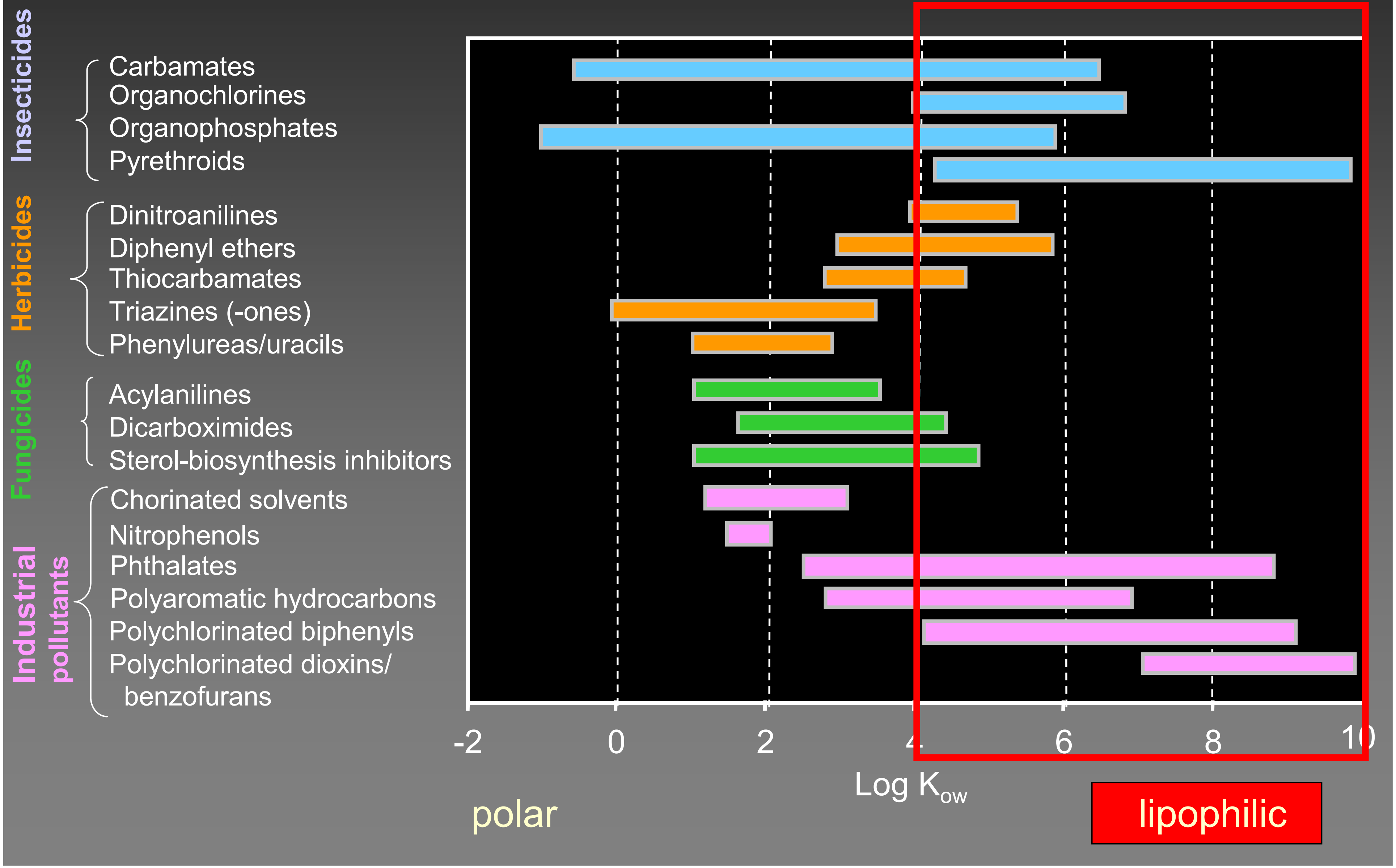
Metabolism and breakdown of organic pollutants determines their availability for long-term processes

Physicochemical properties of pesticides and organic pollutants

The most important properties are:-

- **Lipophilicity** - assessed using the 1-octanol/water partition coefficient, K_{ow} (expressed as log K_{ow} or log P)
- **Water solubility** - strongly correlated with lipophilicity
- **Vapour pressure** – can be important for lipophilic pesticides and pollutants in soil
- **Acid/base strength** - the pKa is the pH at which a functional group is 50% ionised (eg -COOH, $-NH_2$)

1-Octanol/water partition coefficients (K_{ow}) of classes of non-ionised pesticides and pollutants

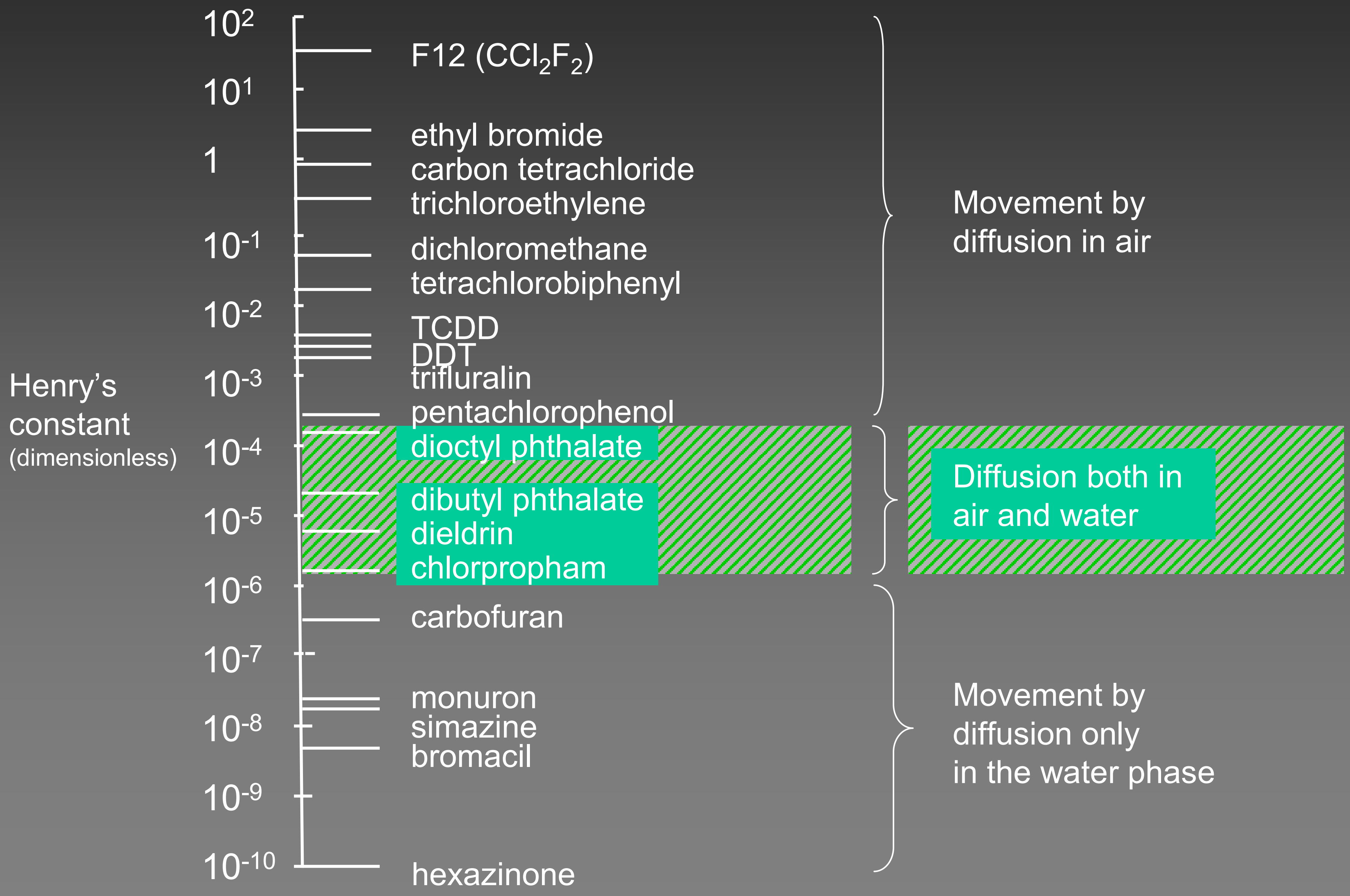


Pathways of compound movement in soil are determined by the Henry Constant:-

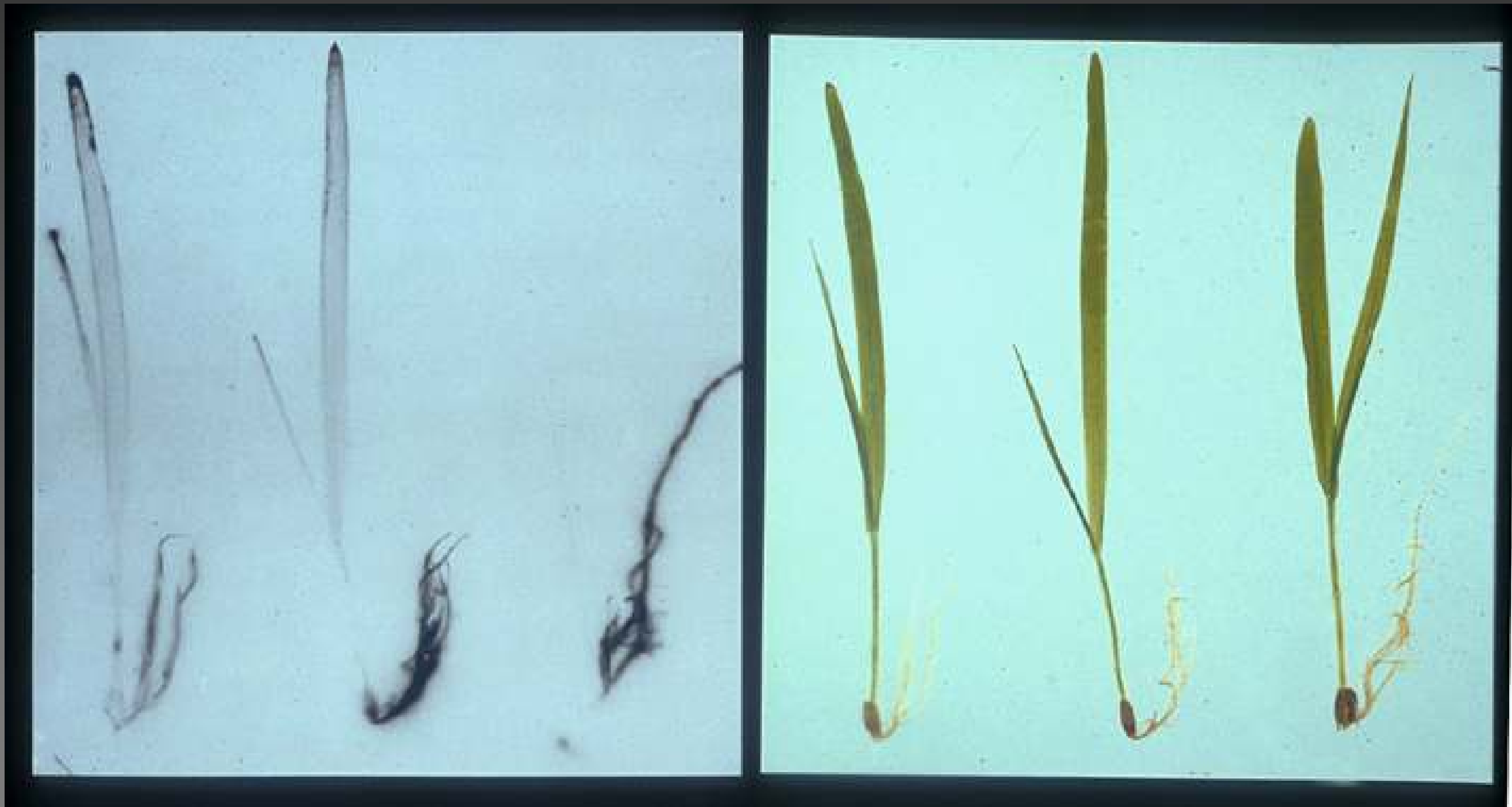
$$\text{Henry constant} = \frac{\text{concentration in air}}{\text{concentration in water}}$$

(calculated from the vapour pressure and water solubility)

Pathways of movement of organic compounds through soil as determined by Henry's constant



Uptake and transport in barley of non-ionised [^{14}C]compounds applied via nutrient solution



polar

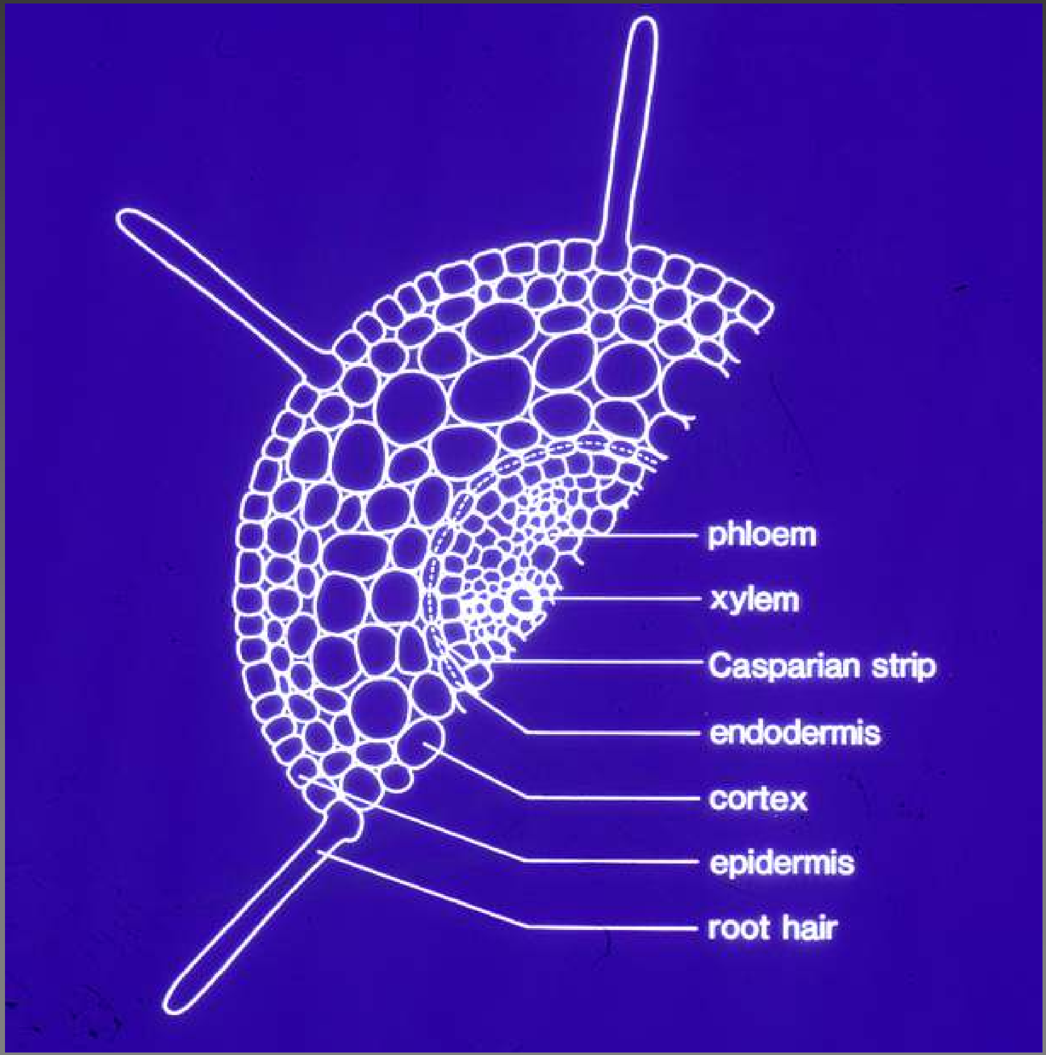
intermediate

lipophilic

Long-distance transport of solutes in plants

- Xylem vessels - non-living tubes that carry water and nutrients from roots to shoots
- Phloem vessels - living tube-like cells without vacuoles that carry sugars and amino acids from leaf sources to sinks such as new growth

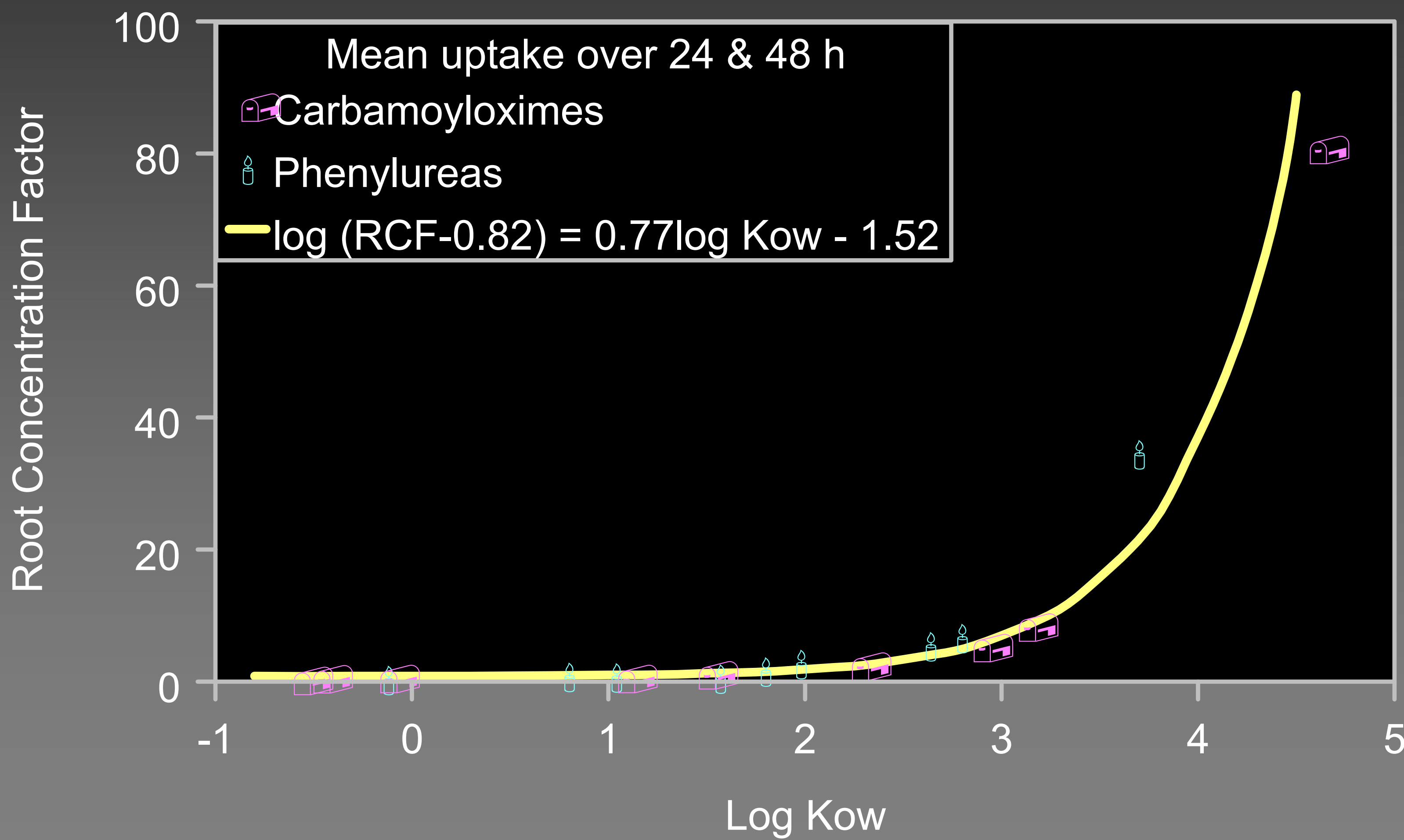
Cross-section of root showing the arrangement of cells and vascular tissues



Root Concentration Factor (RCF)

$$= \frac{\text{concentration in root}}{\text{concentration in nutrient solution}}$$

Relationship between the lipophilicity of non-ionised chemicals and their uptake by barley roots from nutrient solution



Uptake of non-ionised pesticides by plant roots - conclusions

- Uptake is an equilibrium process that is rapidly attained
- Uptake occurs by both equilibration into the aqueous phase of roots and, more importantly for lipophilic compounds, by partitioning into the plant solids (eg lignin)
- The concentration factor is independent of uptake time, pesticide concentration and the solution pH

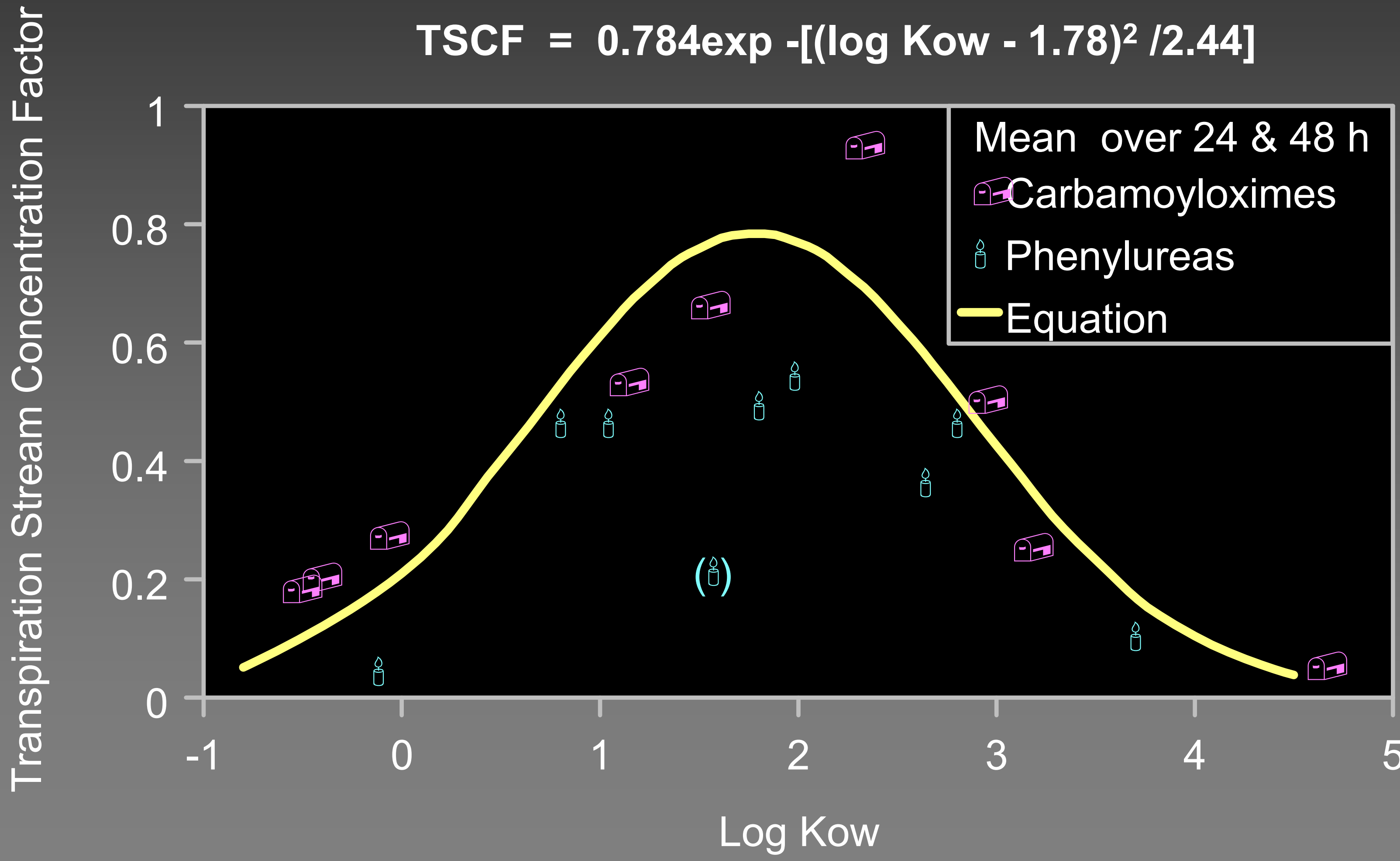
Transpiration Stream Concentration Factor (TSCF)

$$= \frac{\text{concentration in xylem sap}}{\text{concentration in nutrient solution}}$$

$$= \frac{\text{amount in plant shoot}}{\text{vol. water transpired x conc. in nutr. solution}}$$

Relationship between the lipophilicity of non-ionised chemicals and their translocation to barley shoots via root uptake from nutrient solution

TSCF = 0.784exp -[(log Kow - 1.78)^2 /2.44]



Translocation of non-ionised pesticides from roots to shoots - conclusions

- Translocation is an equilibrium process, rapidly attained and limited by the Casparian Strip
- Movement across the membranes is optimal at log Kow 1.8, and less for more polar or more lipophilic compounds
- Translocation is a passive process (TSCF < 1.0)

Conclusions

- Uptake and translocation into plants from soil water are controlled by the physicochemical properties of the compound
- But difficult to model due to uncertainties in the distribution of the compound in soil, the distribution of roots and the source of water
- Vapour transport, important for the more lipophilic compounds both in soil and above soil, is difficult to quantify
- Metabolism in the plant reduces accumulation