LIFE of K

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Acknowledgments

- **Jim Camberato** and the Organizing Committee
- Agronomy Department, College of Agriculture and Life Sciences, Graduate College at **Iowa State University**
- **USDA** - National Institute of Food and Agriculture
- **IPNI** - International Plant Nutrition Institute
- David Laird
- Antonio Mallarino

Three of my favorite movies

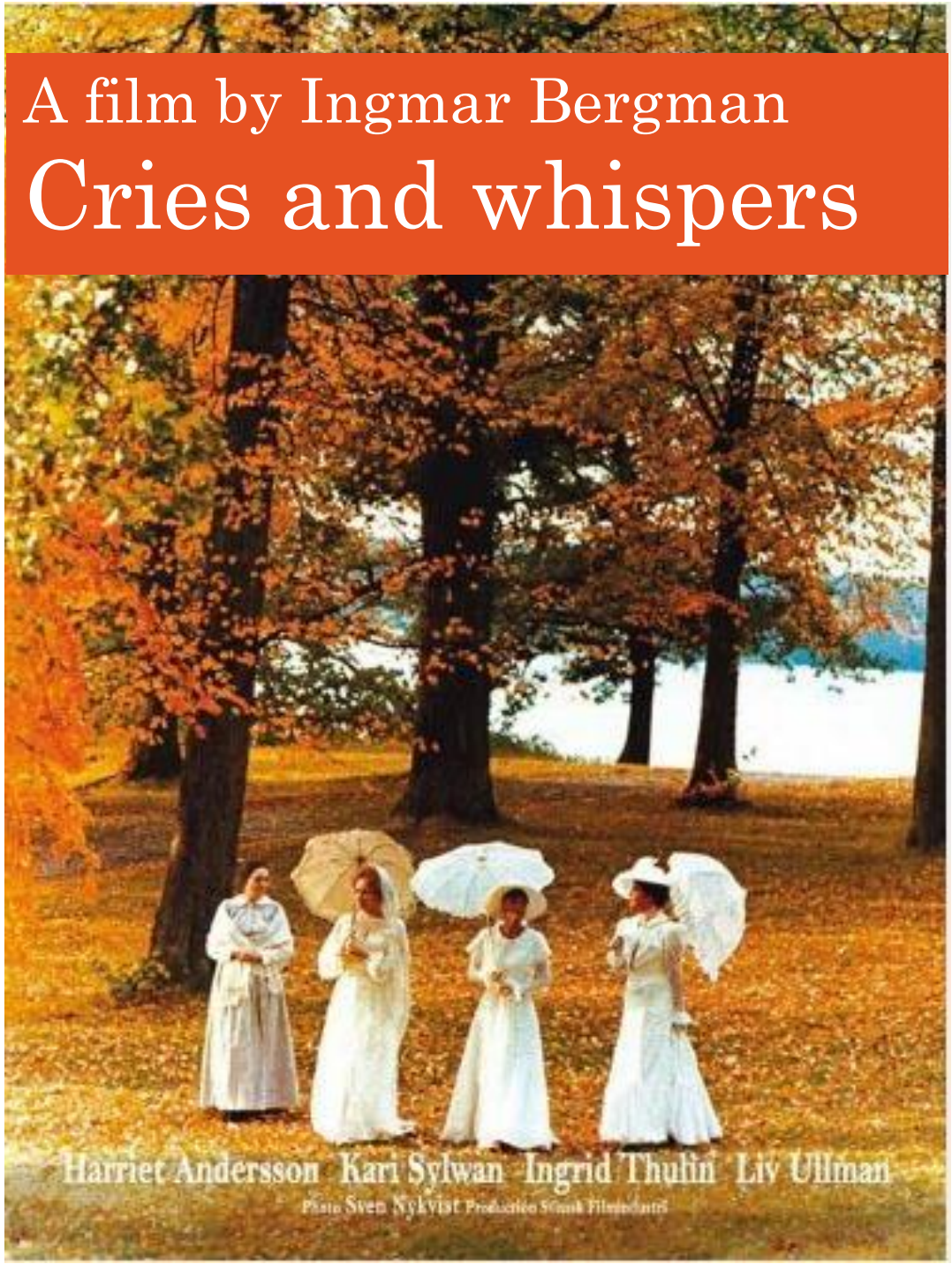
HONEY, I SHRUNK THE KIDS

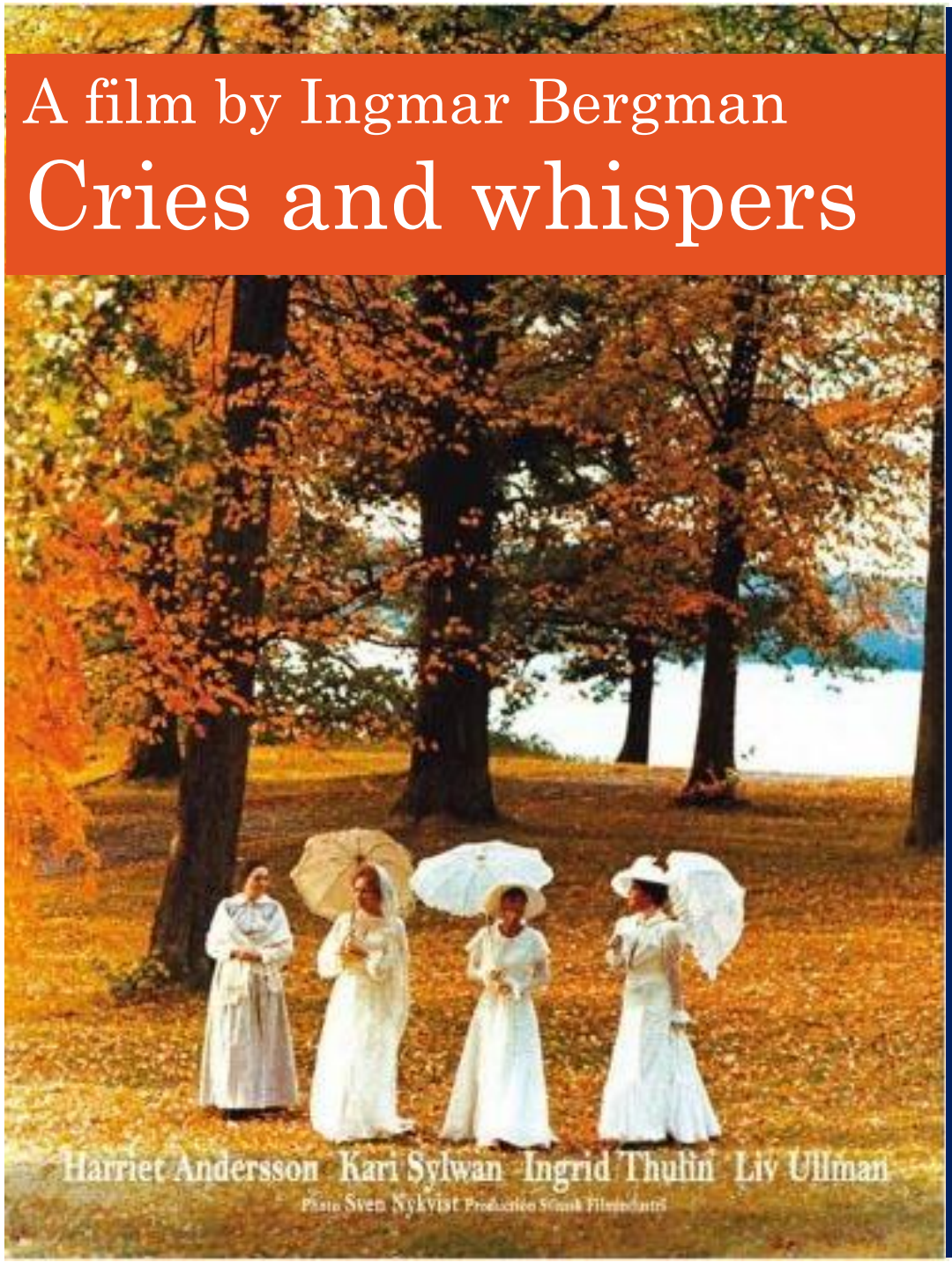
Profound Question:

What can we learn if we get *really small*?

A film by Ingmar Bergman

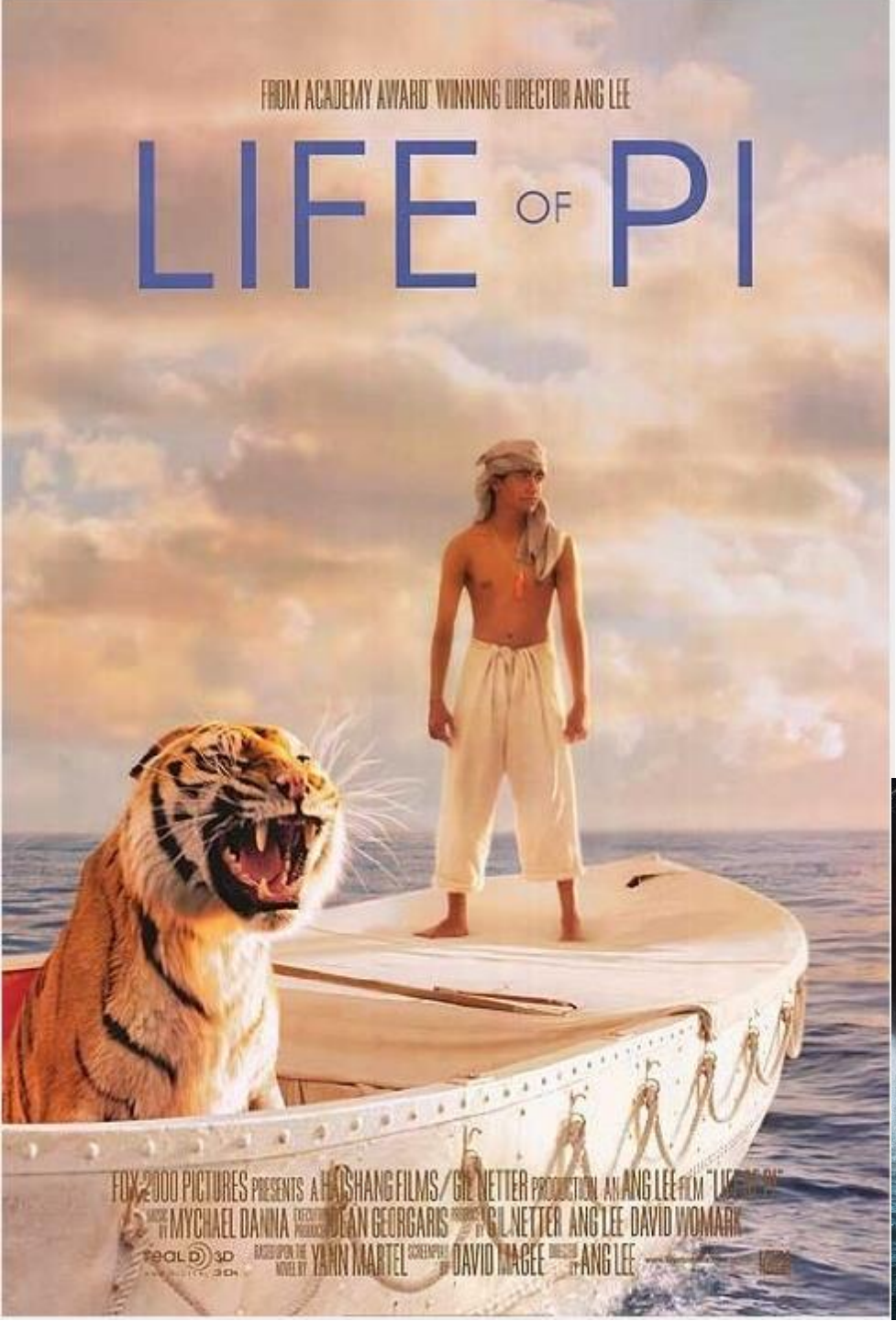
Cries and whispers

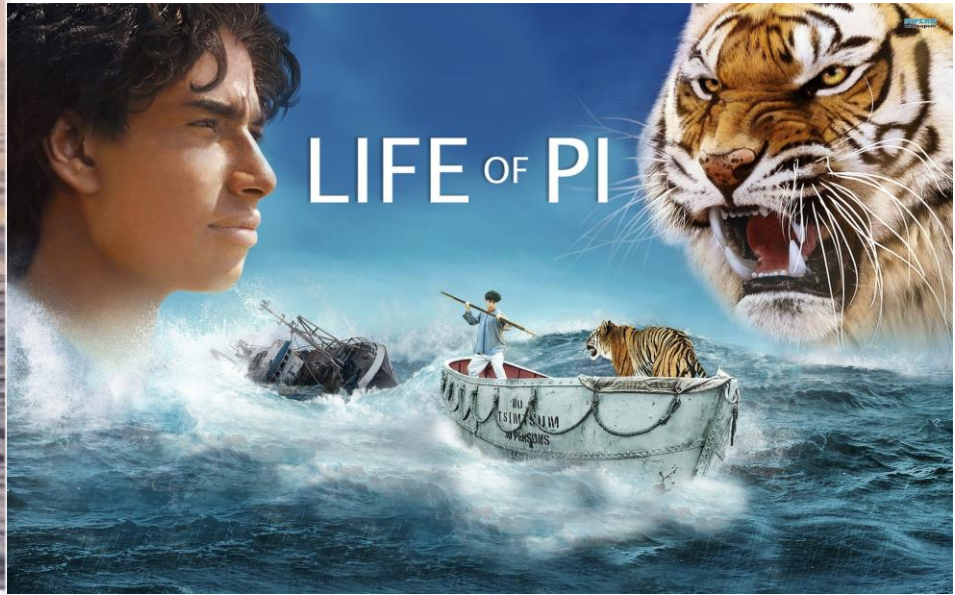


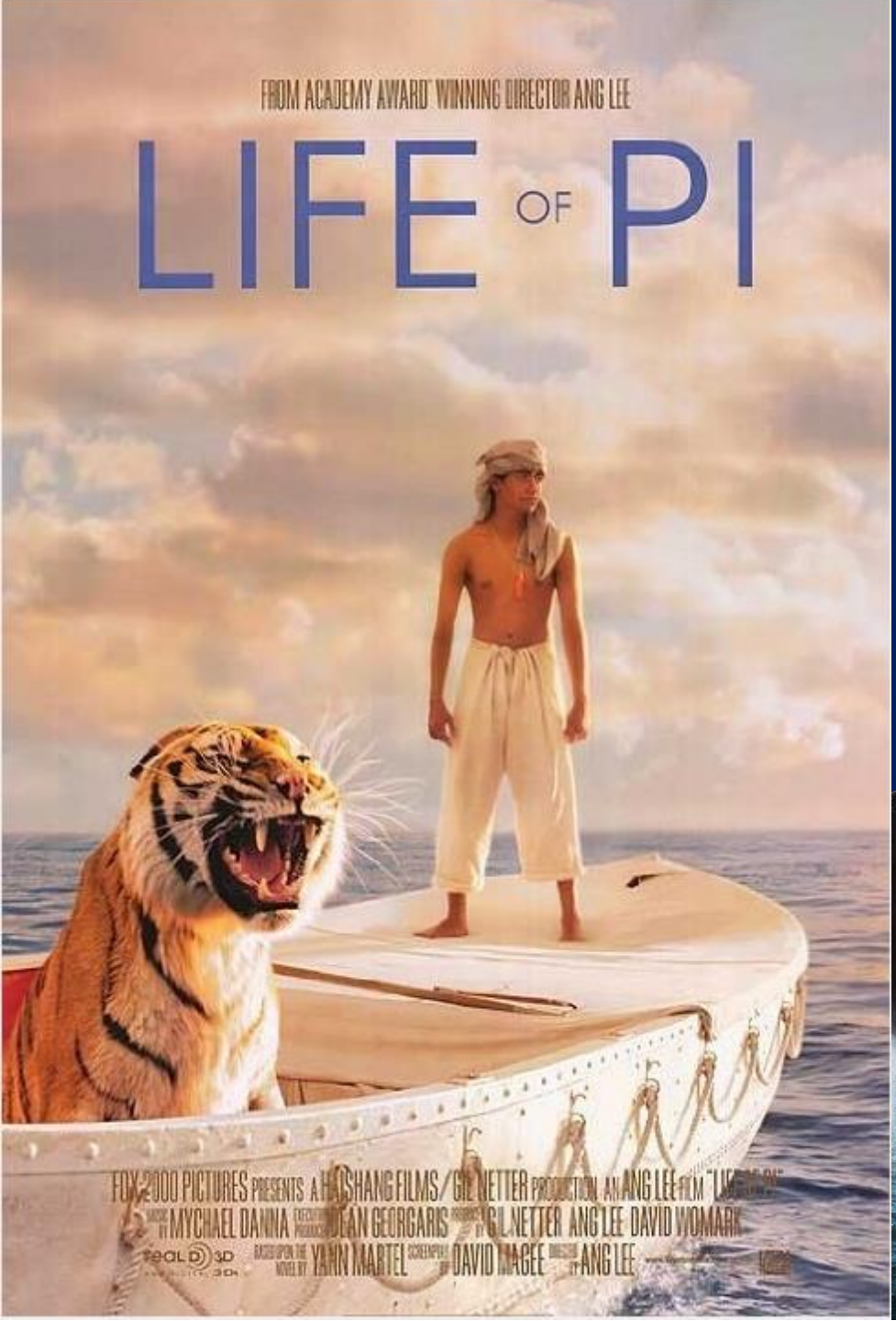


Profound Questions

- What happens after death?
- How does one's life and death shape the next generation?
- How does guilt shape our lives?
- How can we forgive one another?
- How can we best love the people whom we love?


FROM ACADEMY AWARD® WINNING DIRECTOR ANG LEE
LIFE OF PI
FOX 2000 PICTURES PRESENTS
MYCHAEL DANNA
DEAN GEORGARIS
GIL NETTER ANG LEE DAVID WOMARK
BASED UPON THE NOVEL BY YANN MARTEL
DAVID MAGEE
ANG LEE


LIFE OF PI



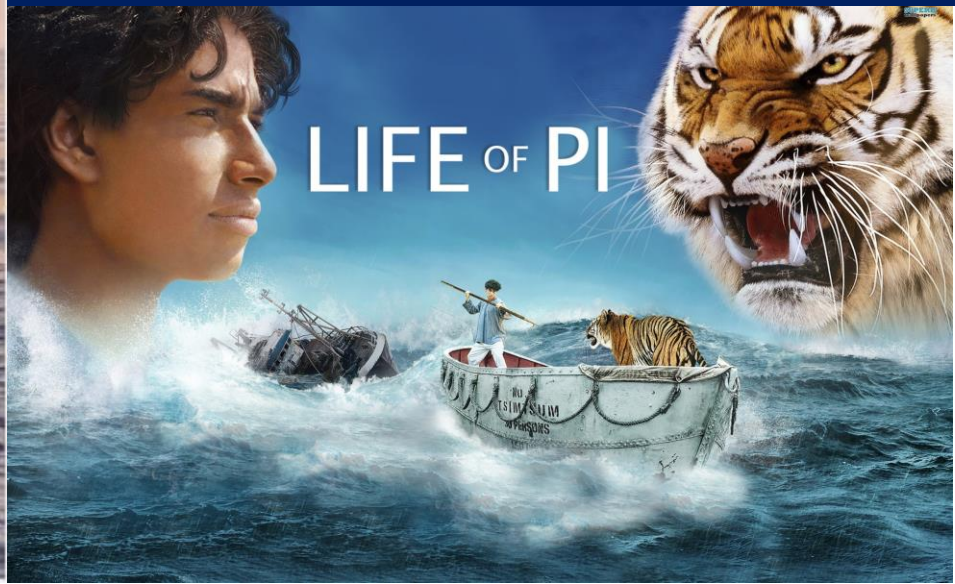
More profound questions

What is reality?

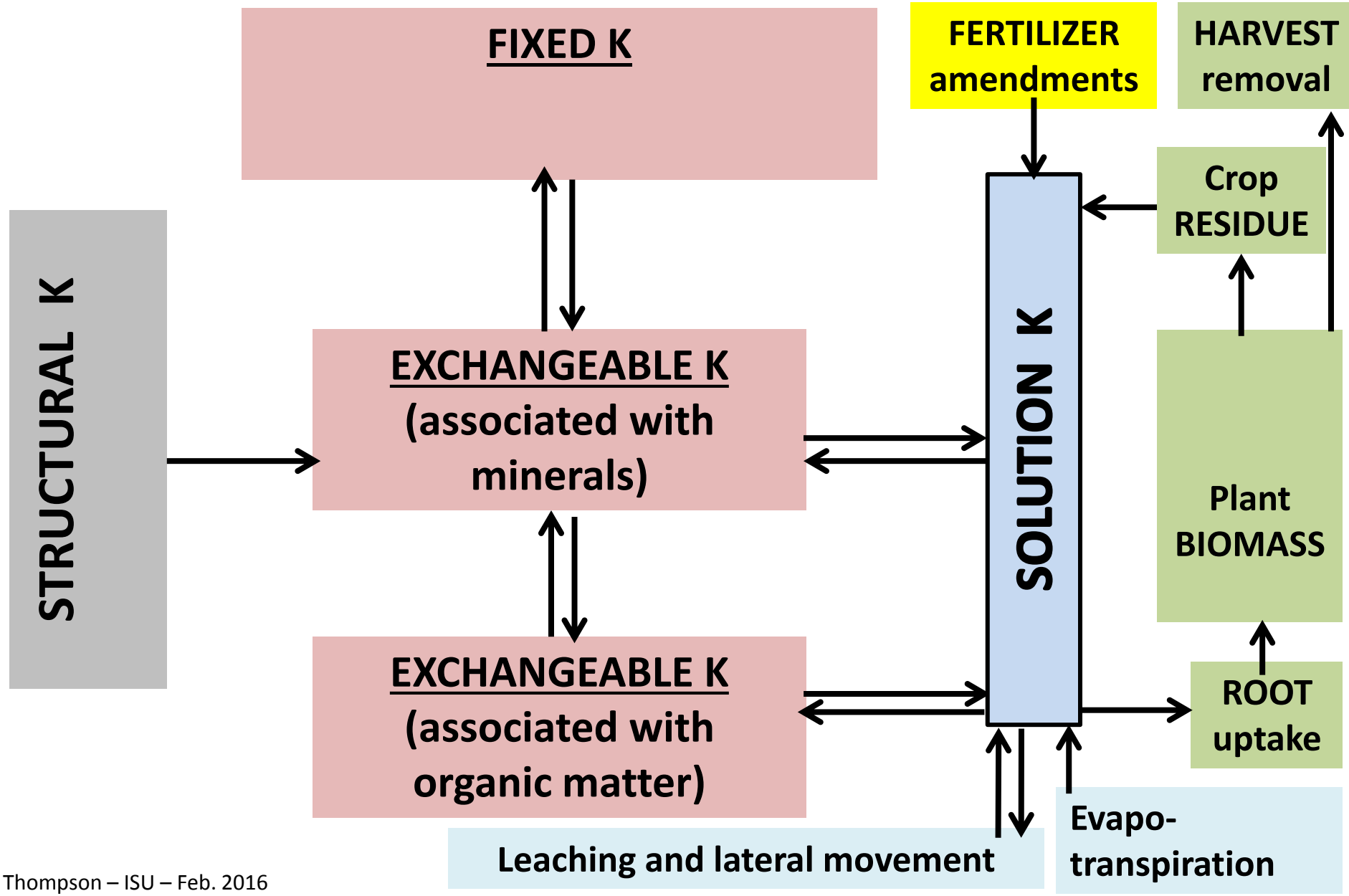
How do we derive meaning from reality?

What are stories?

How do the stories that we tell one another shape our perception of reality?



LIFE of K – *The Cast of Characters*



The Scale of Landscapes

Image by ML Thompson

The Scale of Pedons and Horizons

Image by ML Thompson

The Scale of the Rhizosphere

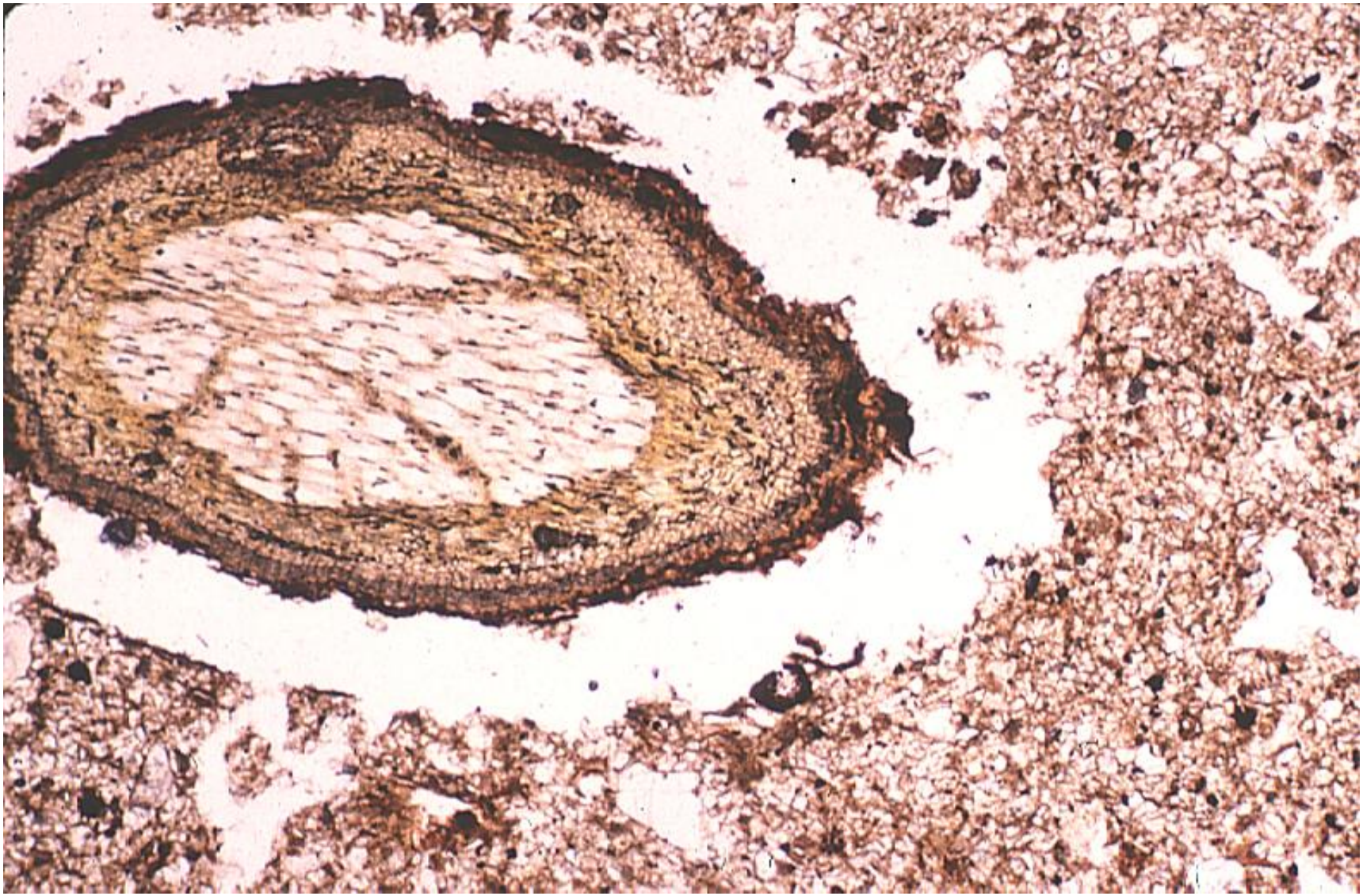


Image by ML Thompson

Intimate mixtures of clay and organic matter

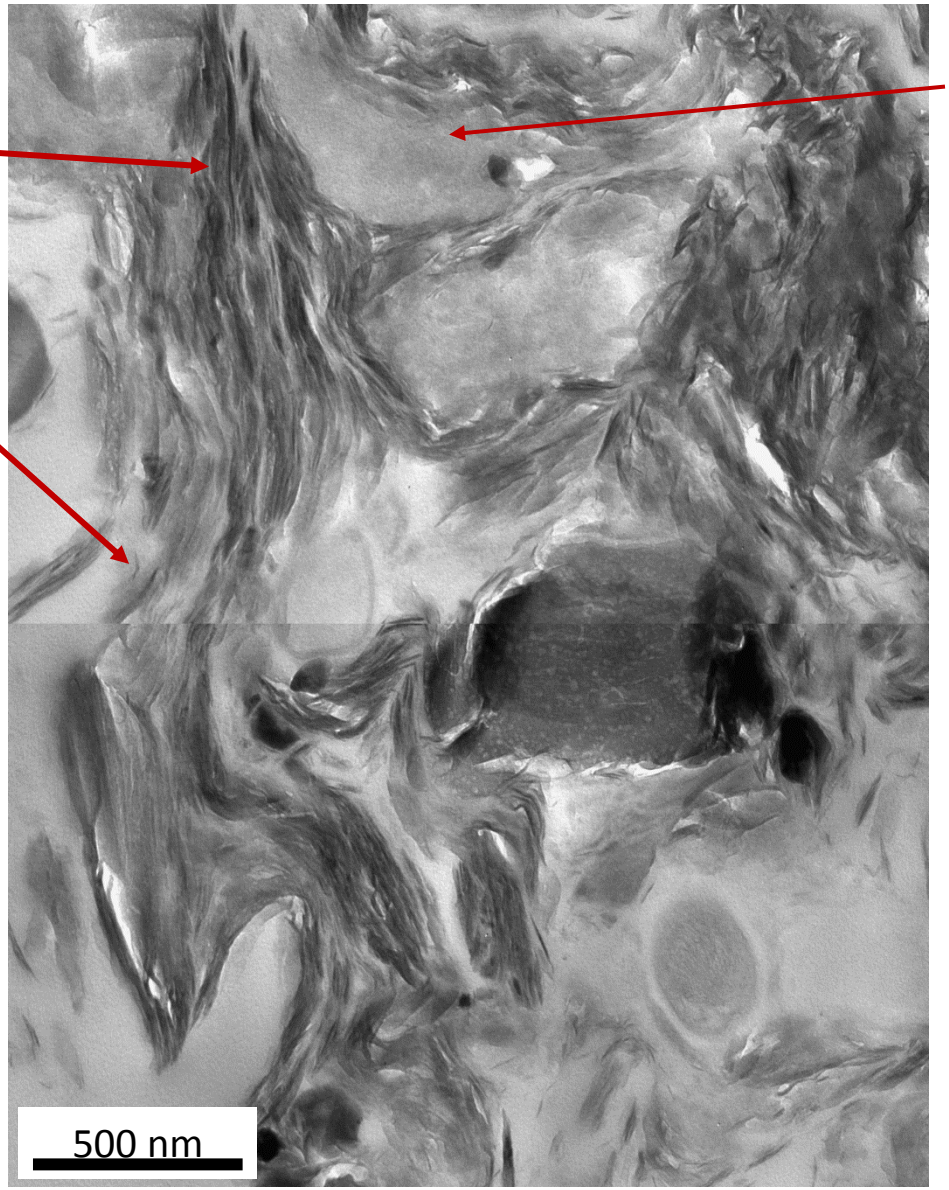


Image by ML Thompson

Intimate mixtures of clay and organic matter

LIFE of K

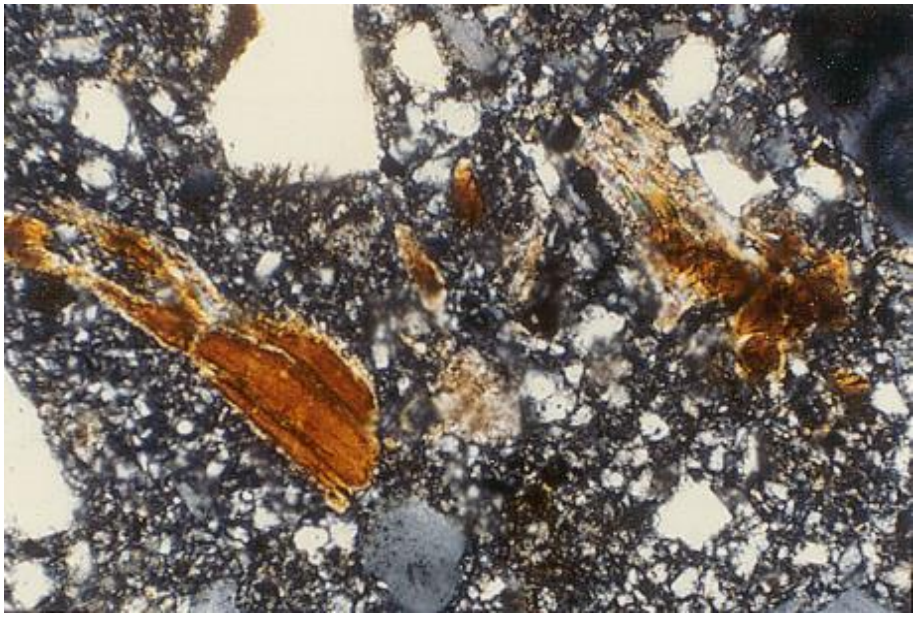
STRUCTURAL K
Micas and Feldspars

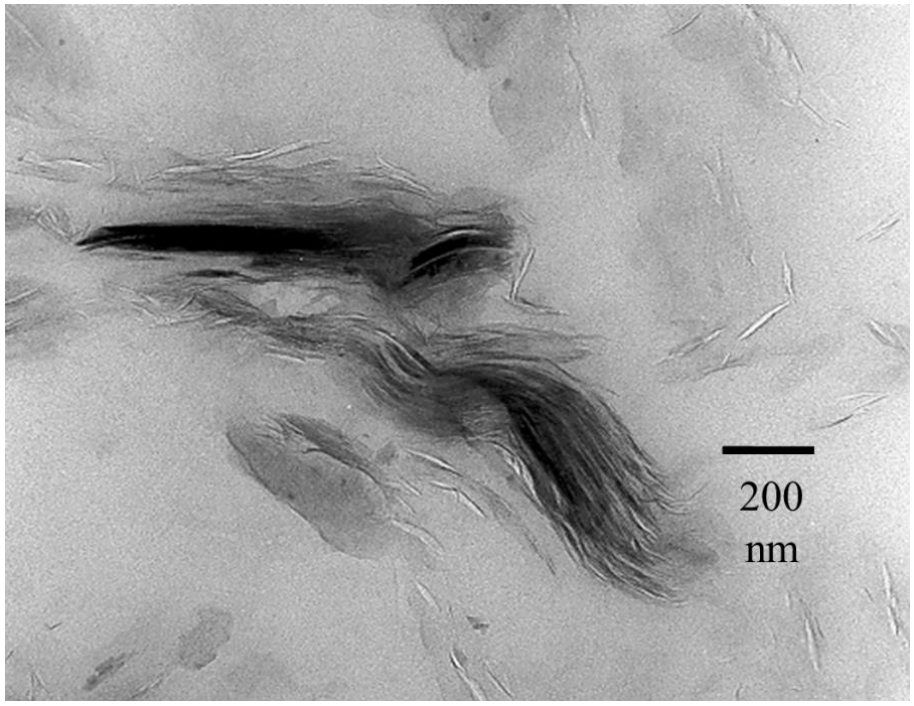
Primary minerals are minerals that crystallize from the magma of volcanic eruptions.

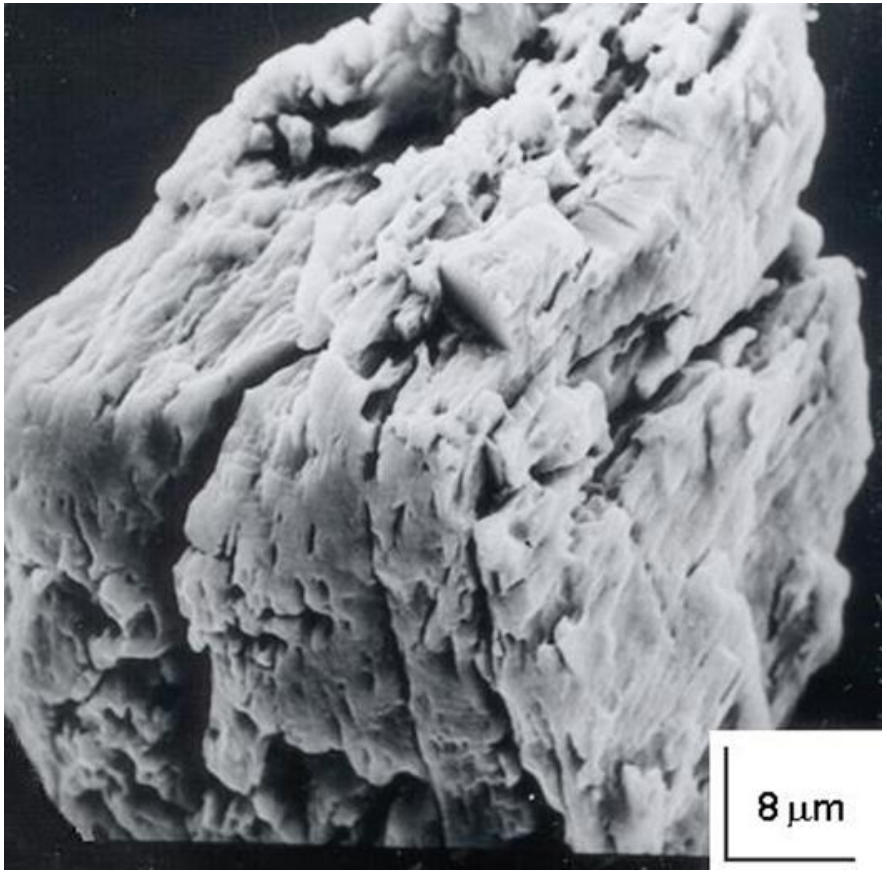
Those that contain K are

- **Micas** (e.g., biotite and muscovite)
- **Feldspars** (e.g., microcline and orthoclase)

Weathered Micas







Images by ML Thompson

LIFE of K: *Birth*

Primary minerals “weather” – break down – by several mechanisms.

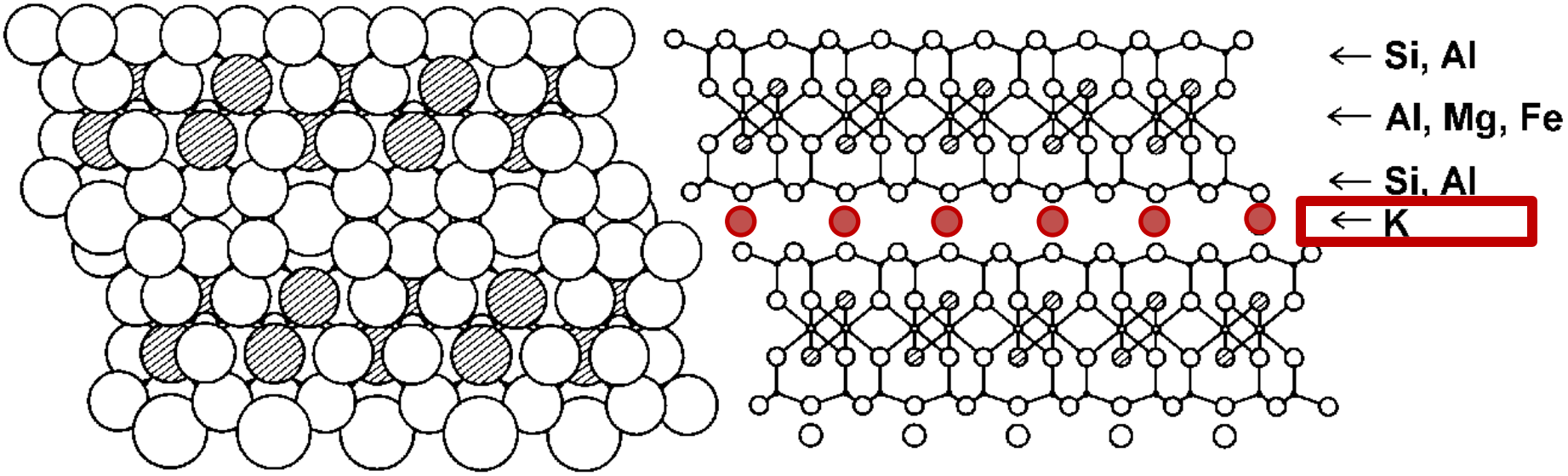
- Chemical bonds are destabilized by acid attack.
- Al ions are complexed by organic anions and kept in solution, destabilizing the crystal.
- Fe^{2+} ions in micas are oxidized to Fe^{3+} ions, lowering the negative charge and releasing K^{+}.

Weathering releases K to the soil solution.

Once released from primary minerals, where do K ions go – if not to plants?

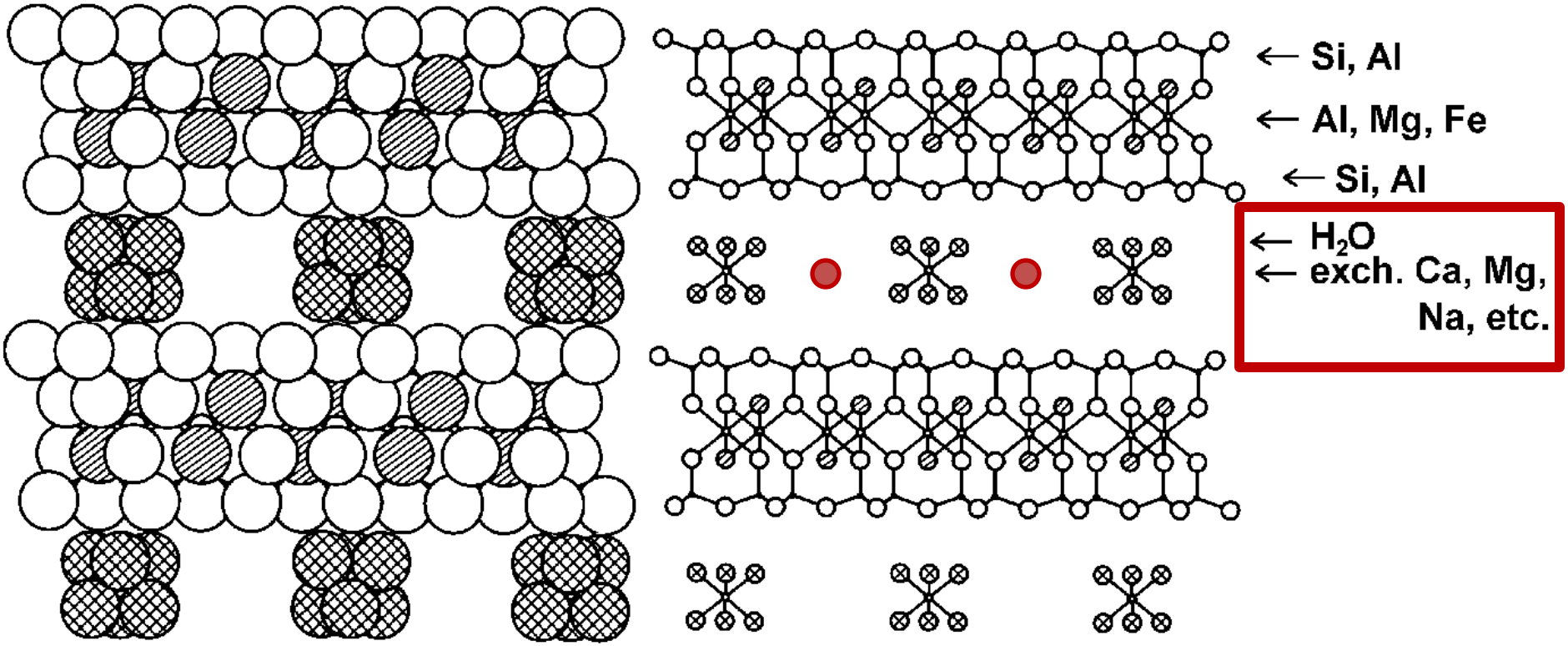
Before answering that question, let's take a slight detour to recall the basic characteristics of layer silicate clay minerals.

Mica



- K-bearing minerals: **biotite** and **muscovite**
- Defined as *layer silicates* with **nonexchangeable K**

Vermiculite and Smectite

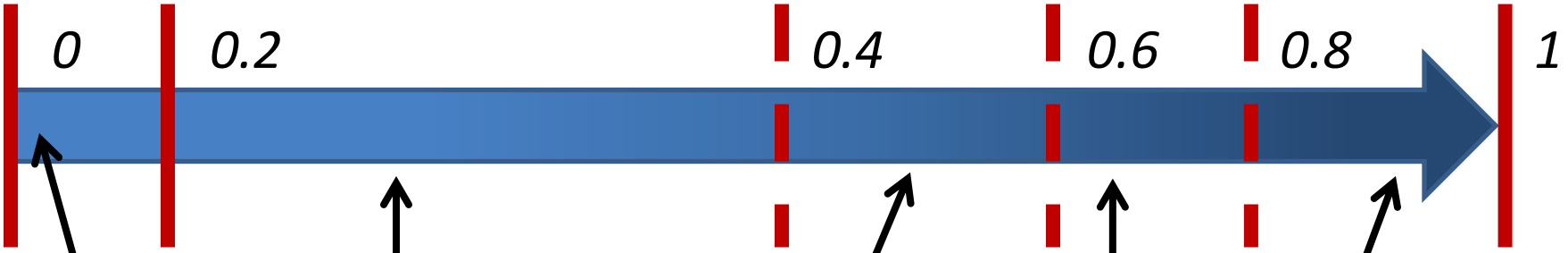


Vermiculite is a high-charge mineral, mainly derived from biotite.

Smectites may range in charge, but the higher the charge the more likely they are to “fix” K.

Layer Silicate Classification

moles of charge per 10-oxygen formula unit



Kaolinite

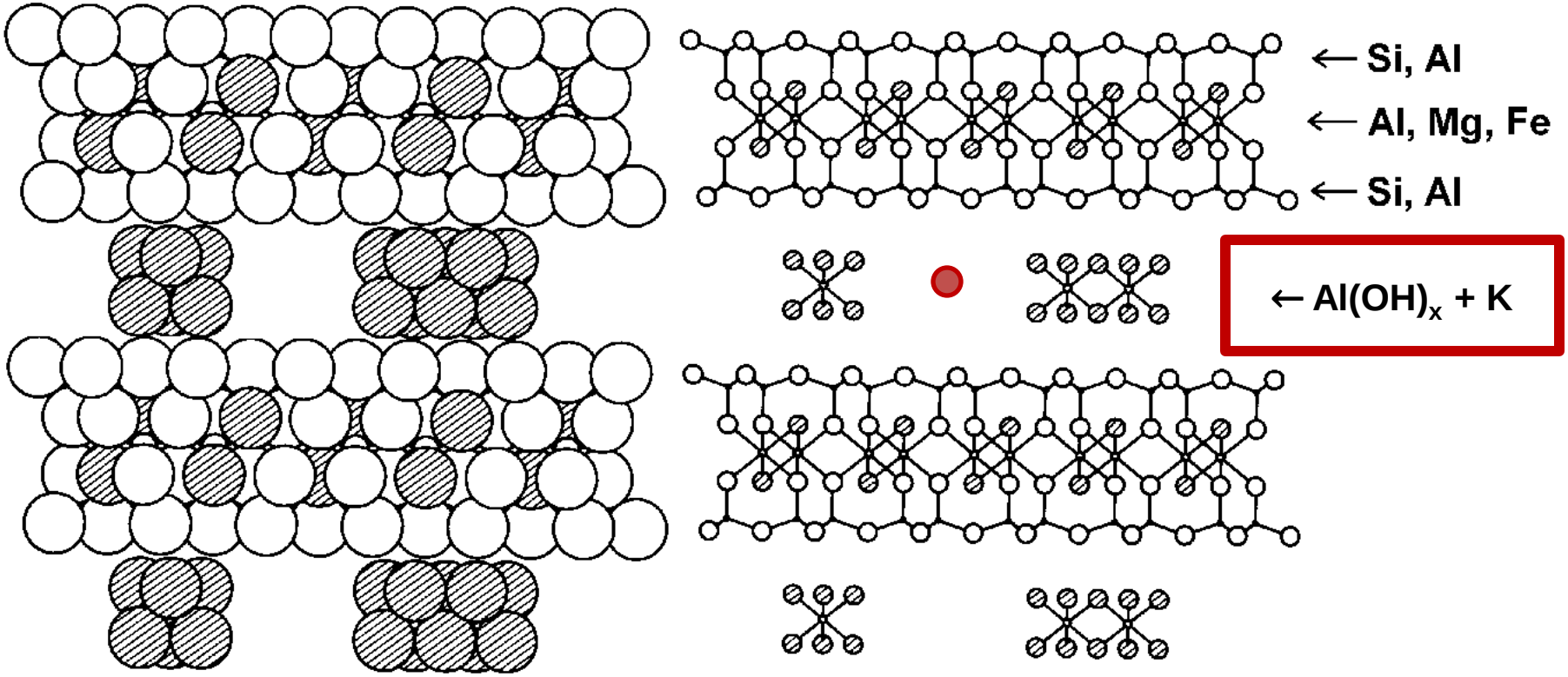
Low-charge smectite (e.g., montmorillonite)

High-charge smectite (e.g., beidellite)

Vermiculite, illite (?)

Micas (e.g., biotite, muscovite, illite?)

Hydroxy–interlayered Vermiculite and Smectite

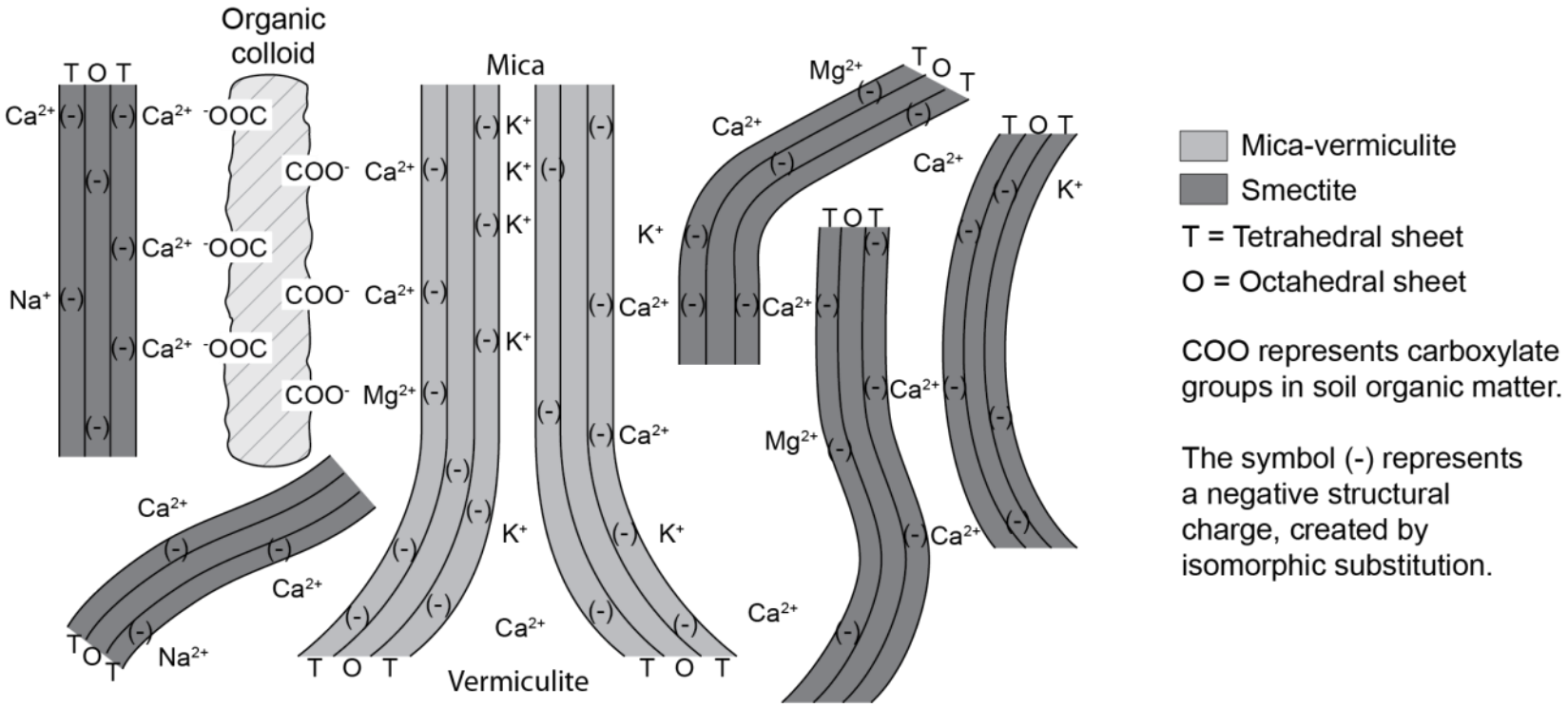


In **acidic** soils, *vermiculite* and *smectite* can be “pillared” with hydroxy-Al polymers. These materials are called interlayered vermiculite and smectite.

Where do K ions go?

- Potassium ions (**positively** charged) are attracted to the **negatively** charged surfaces of 2:1 clay minerals.
- In the case of low-charge ***smectite***, the attraction is weak, but there is a lot of surface area to retain cations like potassium.
- In the case of ***vermiculite***, the attraction is stronger, because the negative charge is higher or because the negative charge sites are closer to the surface of the tetrahedral sheet.
- The proportions of these minerals in the clay fractions of soils in the North Central region are highly variable. In the real world of soils, clay minerals commonly occur "*interstratified*" with one another, which means that a single clay layer may grade from mica to vermiculite to smectite.

LIFE of K – *Young adulthood* – A little fish in a big pond: Competition

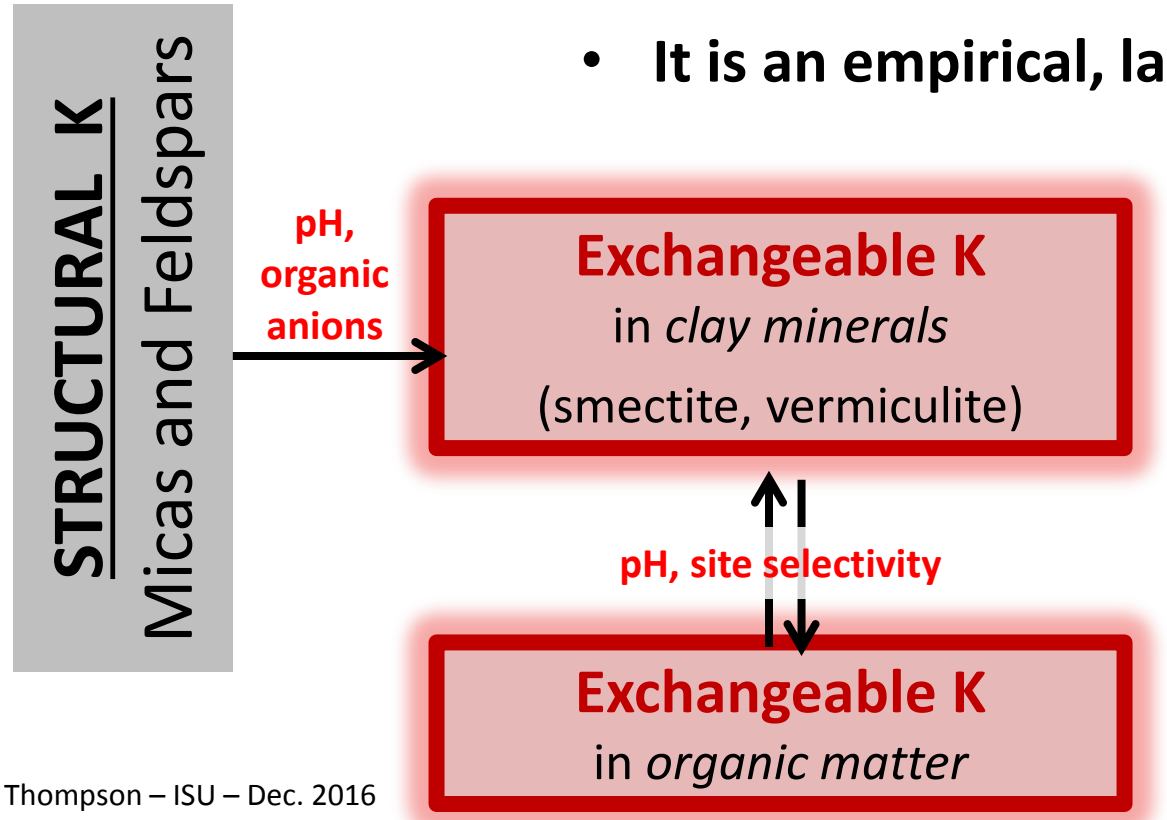


- **Exchangeable K^+** is held loosely near negatively charged mineral surfaces or negatively charged organic functional groups.
- Other cations, such as Ca^{2+}, Mg^{2+}, and NH_4^+ compete dynamically with K for these negatively charged sites and surfaces.

LIFE of K

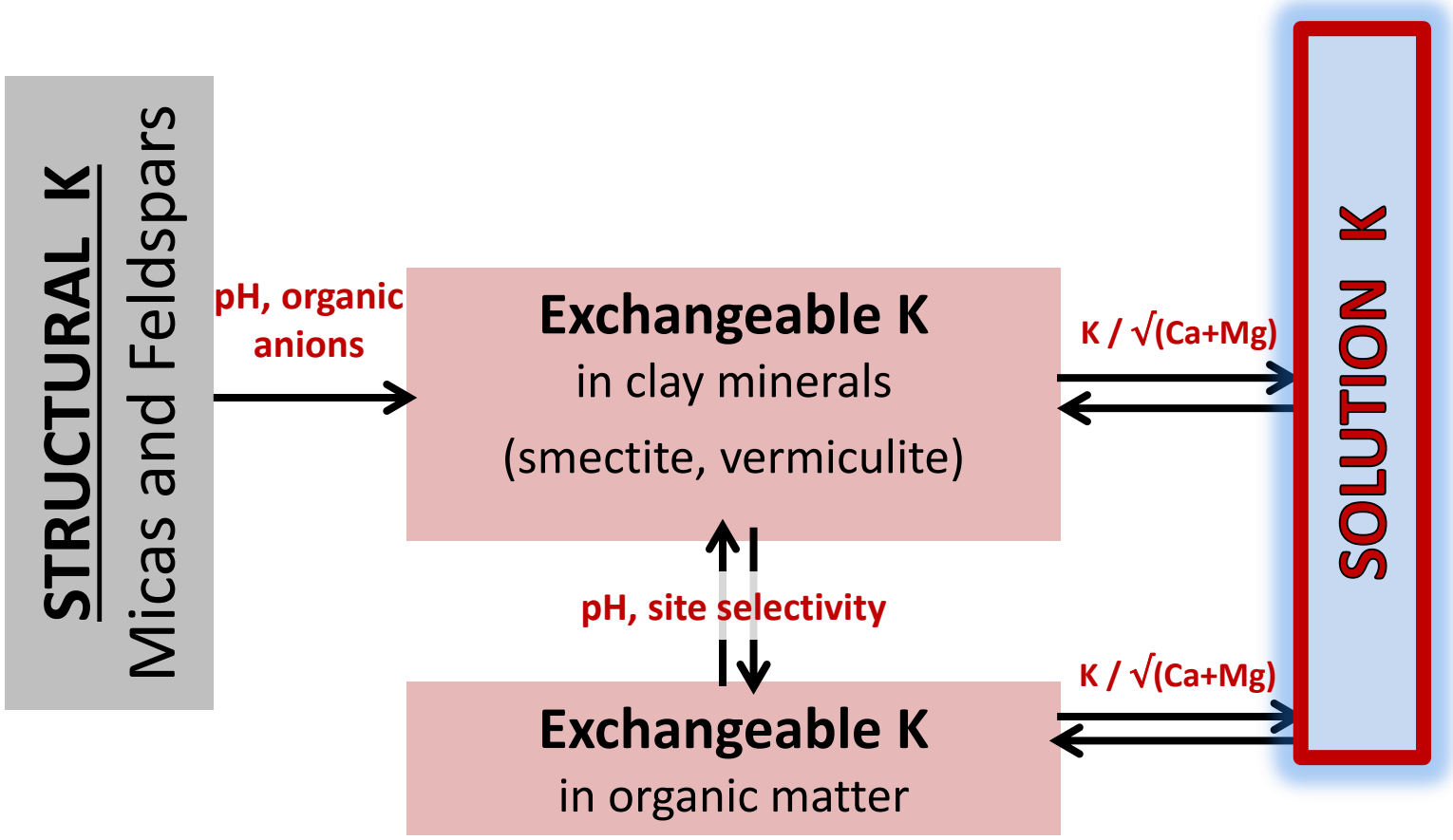
Exchangeable potassium is

- K^+ that can be flushed from the solid phase with NH_4^+ ions (or other cations).
- K^+ that is extractable using ammonium acetate, ammonium nitrate + ammonium fluoride (Mehlich-3), or calcium lactate.
- **It is an empirical, lab-based definition**.



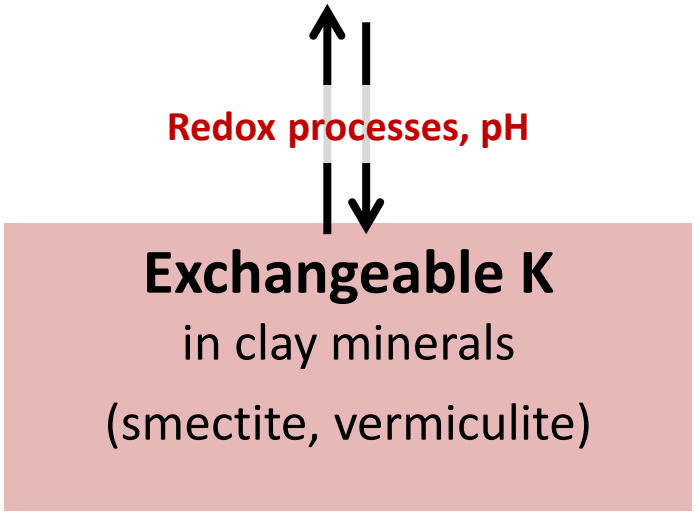
***Exchangeable* K is roughly correlated with**
but does not equal *bioavailable* K.

LIFE of K


STRUCTURAL K
Micas and Feldspars
pH, organic anions
Exchangeable K
in clay minerals
(smectite, vermiculite)
K / √(Ca+Mg)
SOLUTION K
pH, site selectivity
K / √(Ca+Mg)
Exchangeable K
in organic matter

LIFE of K – *Taking a wrong turn*

You can get in with the wrong crowd – get too close to certain minerals – and the next thing you know …



LIFE of K – *Taking a wrong turn*

You can get in with the wrong crowd – get too close to certain minerals – and the next thing you know …

Fixed K

Edge sites: Dioctahedral vermiculite

Redox sites: Trioctahedral vermiculite and high-charge smectite

Interlayer sites: Hydroxy-interlayered vermiculite and smectite

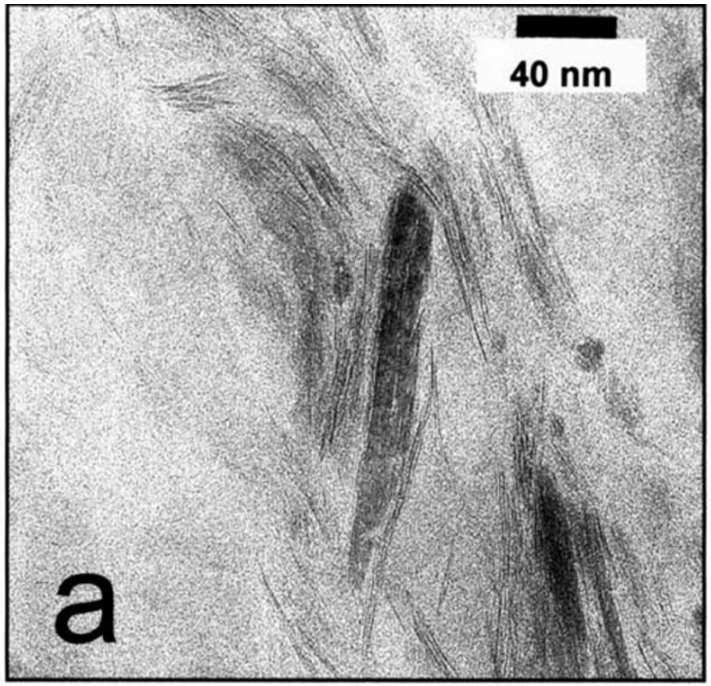
Redox processes, pH

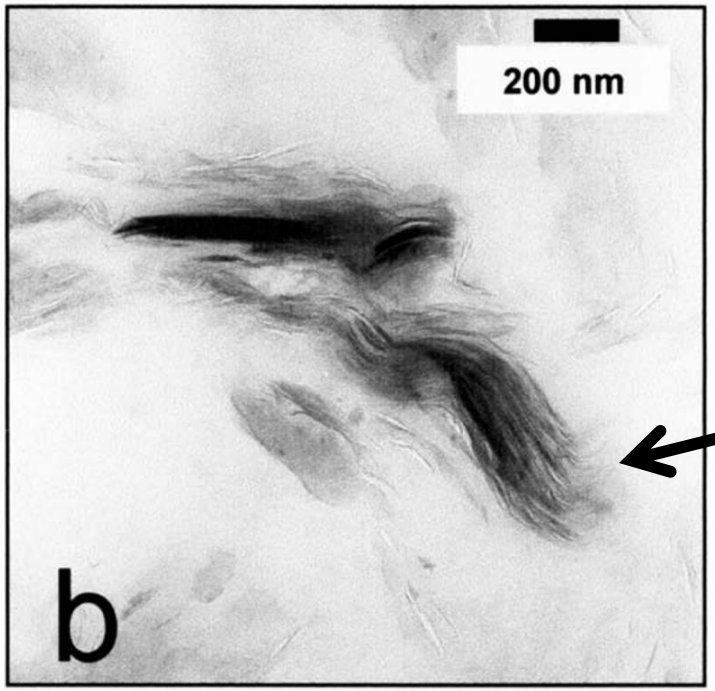
Exchangeable K

in clay minerals

(smectite, vermiculite)

Boom! You are in the slammer.





Images by ML Thompson

Sites for K fixation

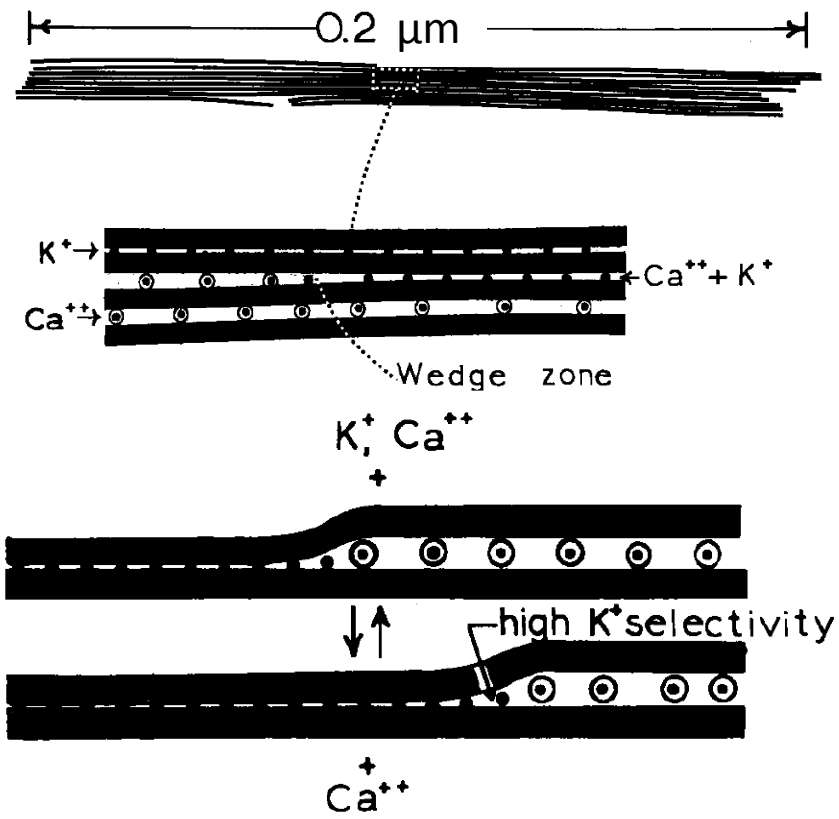
a) Randomly interstratified mica-smectite in the fine clay (<0.2 µm) dispersed from Typic Argiudoll in Iowa.

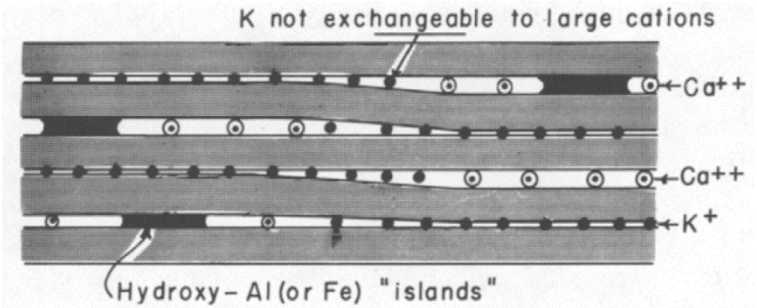
b) Clay mica particle dispersed from a fine, smectitic, Quaternary paleosol in Iowa.

Note frayed, vermiculitic edges where monovalent cations such as K^+ or NH_4^+ might be fixed.

We have known about K fixation for decades.

- Vermiculite fixes K.
- Sites in wedges and at frayed edges of “micas” are selective for K.
- Hydroxy-interlayered vermiculite fixes K.





LIFE of K – *Unexpected grace*

Fixed K

Edge sites: Dioctahedral vermiculite

Redox sites: Trioctahedral vermiculite and high-charge smectite

Interlayer sites: Hydroxy-interlayered vermiculite and smectite

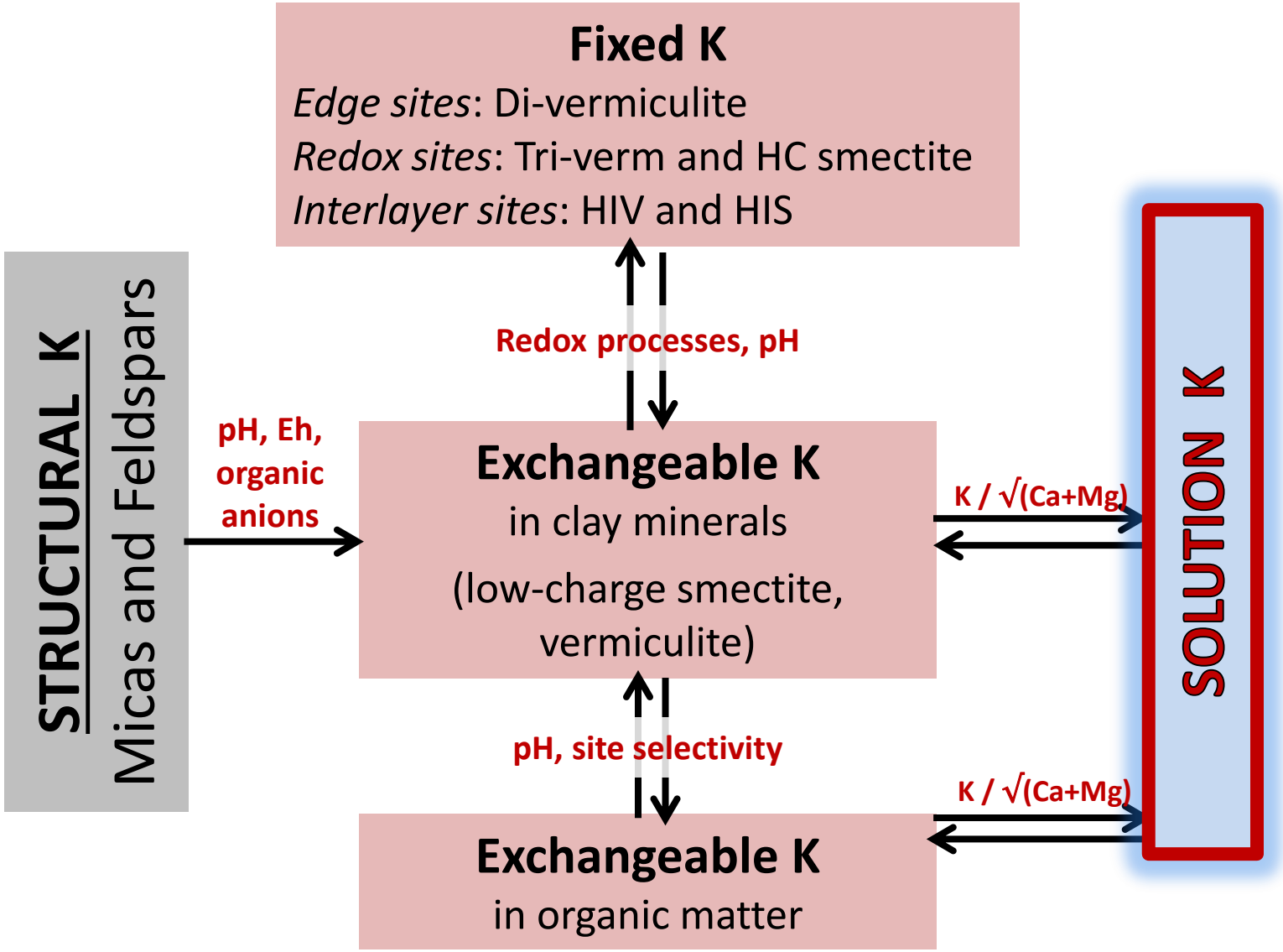
Redox processes, pH

Exchangeable K

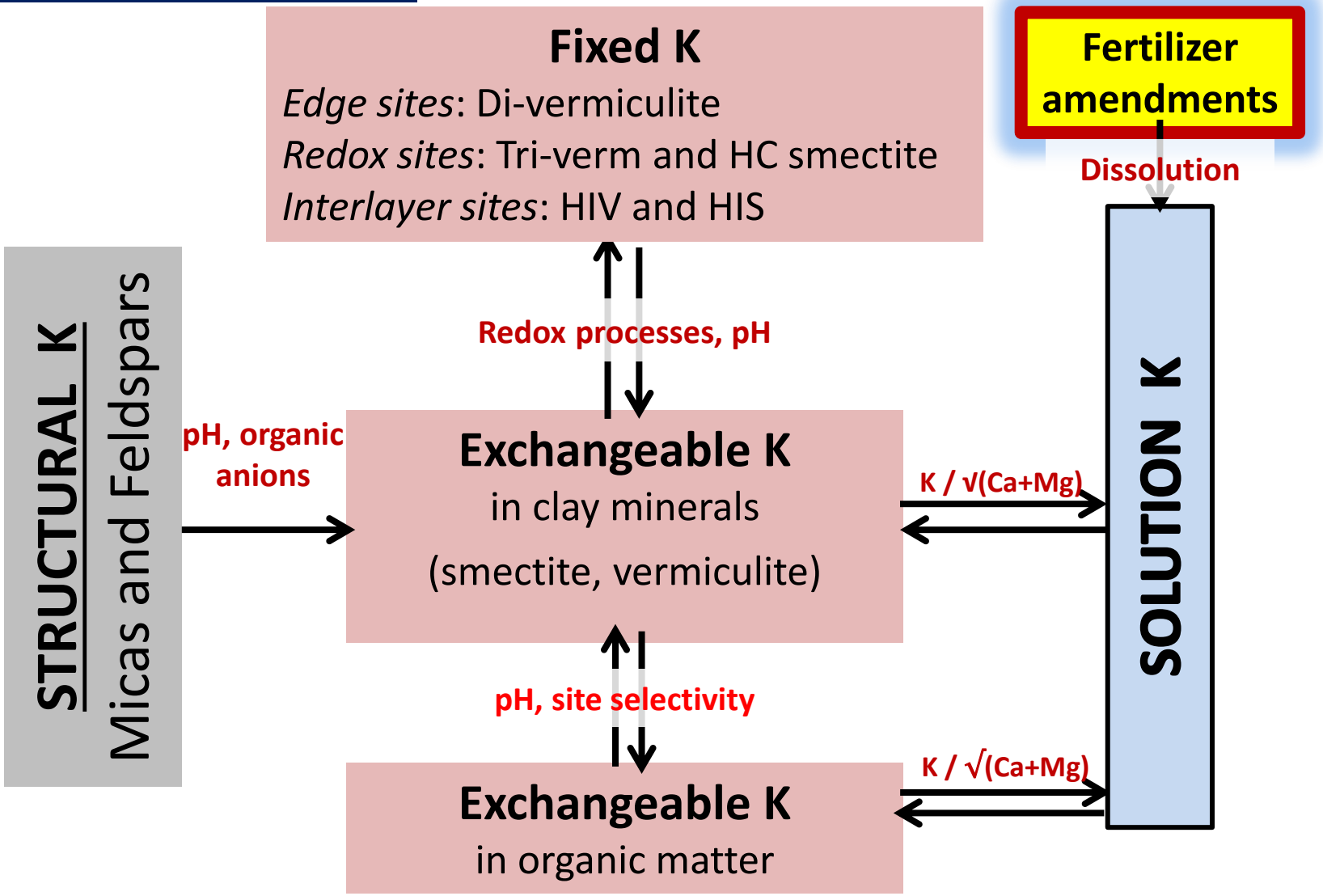
<u>The unexpected grace of fixed K's release is not easily predicted</u>

- Low K^+ concentration in solution due to plant uptake
- Increase in oxidation state of Fe as drainage conditions improve may lower the effective CEC and release K from fixed sites

LIFE of K


Fixed K
Edge sites: Di-vermiculite
Redox sites: Tri-verm and HC smectite
Interlayer sites: HIV and HIS
STRUCTURAL K
Micas and Feldspars
Redox processes, pH
pH, Eh, organic anions
Exchangeable K
in clay minerals
(low-charge smectite, vermiculite)
K / √(Ca+Mg)
SOLUTION K
pH, site selectivity
K / √(Ca+Mg)
Exchangeable K
in organic matter

LIFE of K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Fertilizer amendments
Dissolution
STRUCTURAL K
Micas and Feldspars
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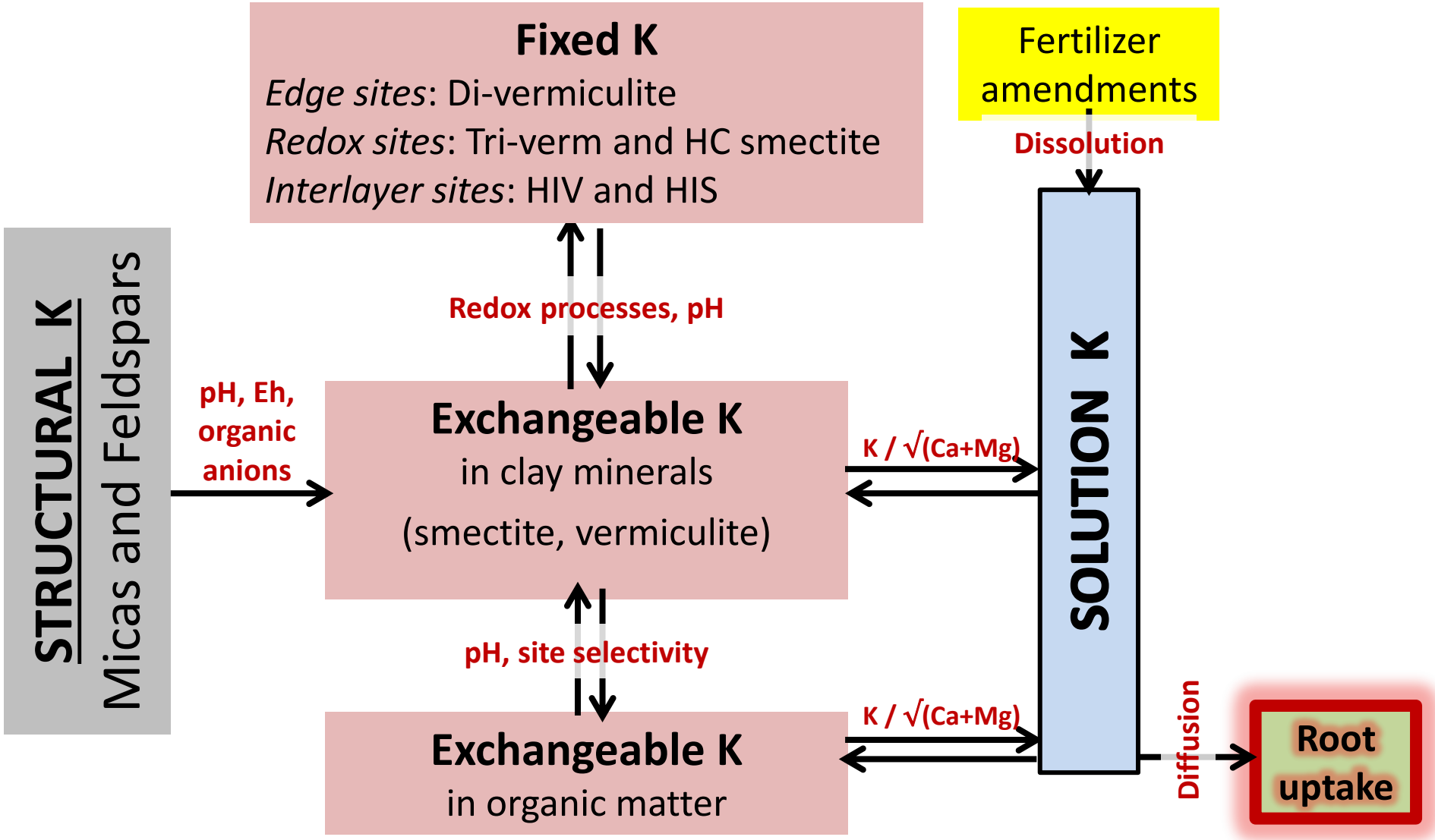
LIFE of K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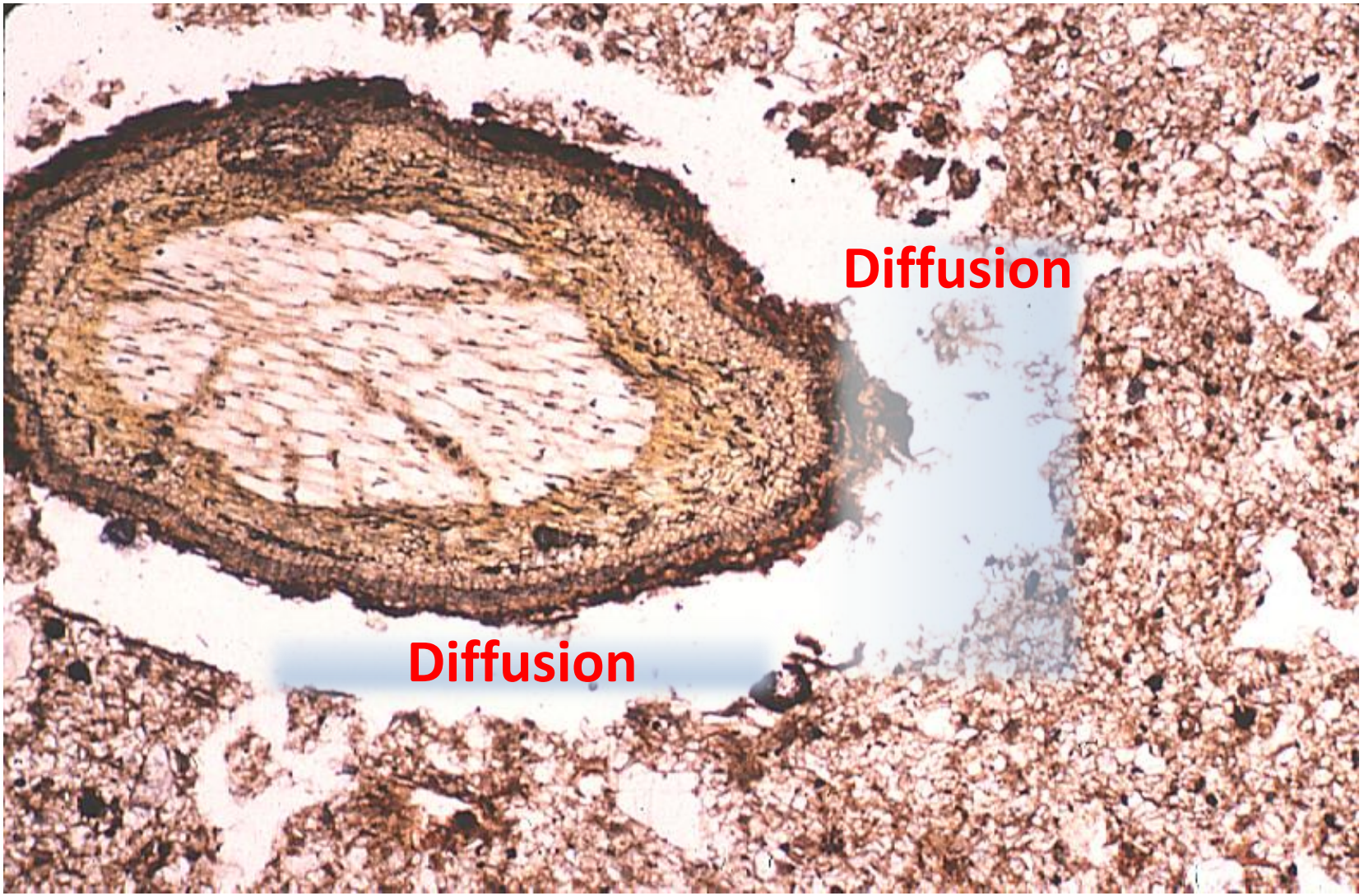
Diffusion
Root uptake

LIFE of K – *Few are selected* – Diffusion limits movement into roots



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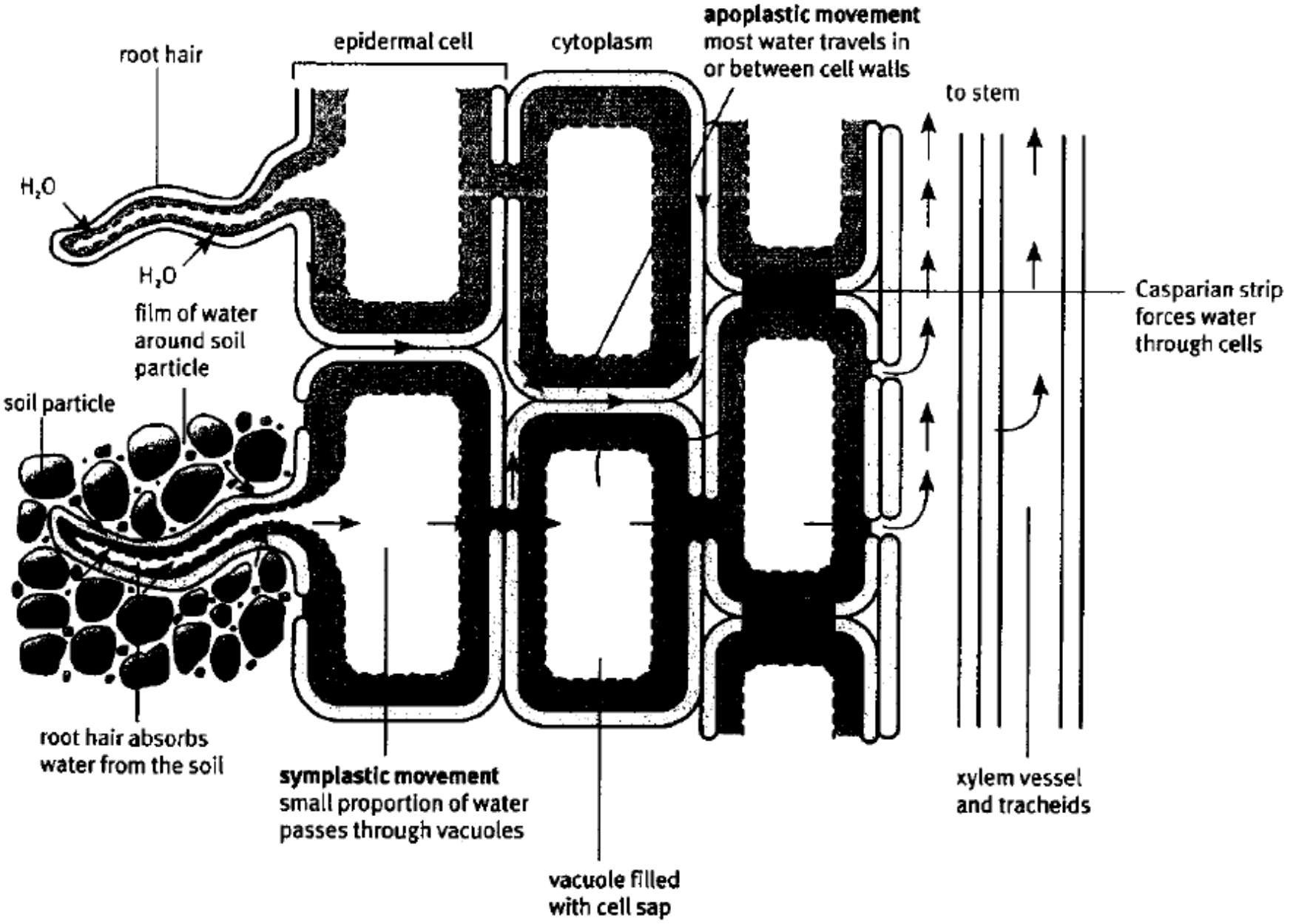
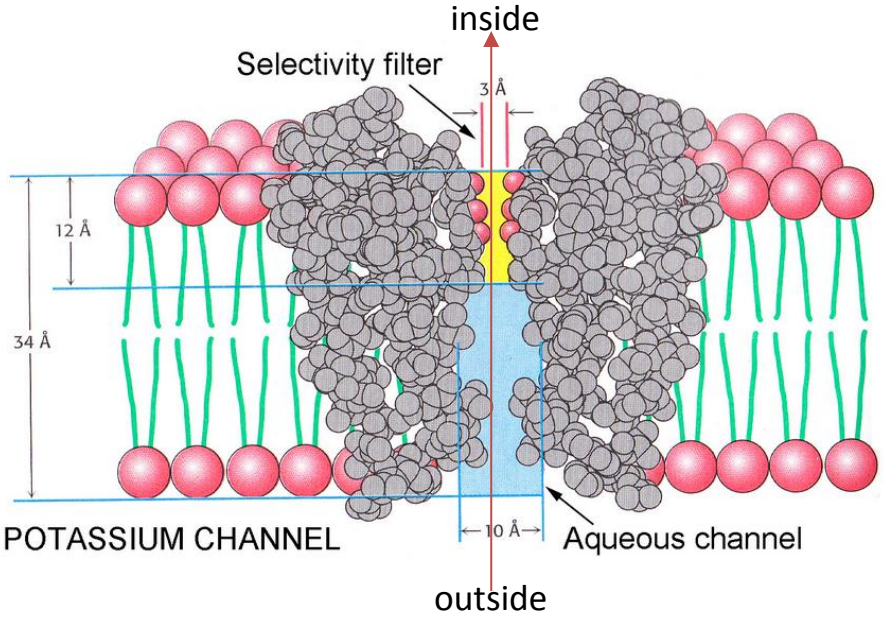
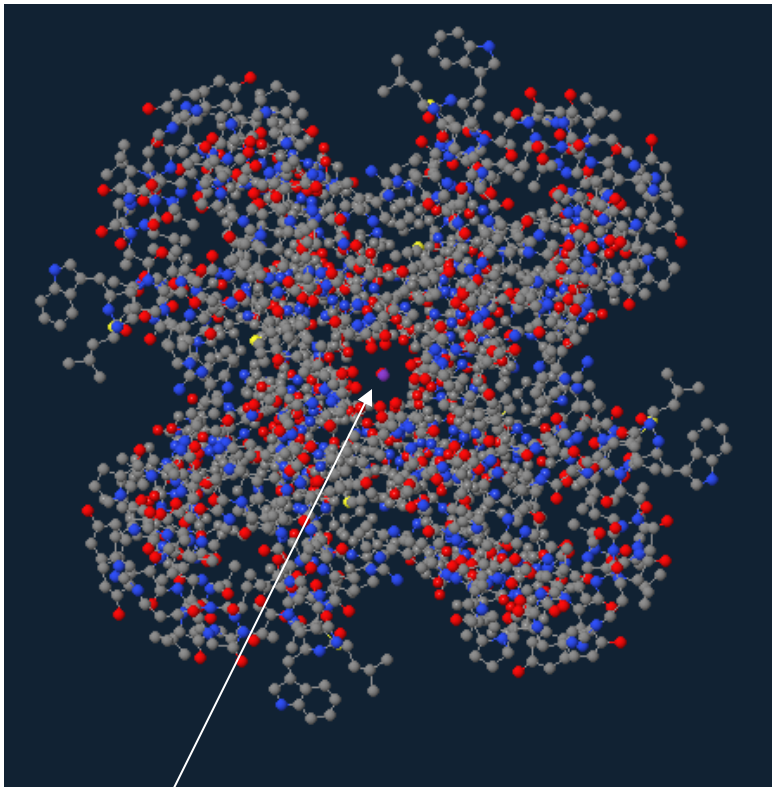


Anatomy of dicotyledenous plants. http://cnx.org/contents/pPKTz_LG@1/211---Anatomy-of-dicotyledenou

Potassium Transport Through a Cell Membrane Requires a Protein Channel

Protein channels and carrier proteins transport ions through cell membranes against a concentration gradient, from a region of low concentration to a region of high concentration.





Top view

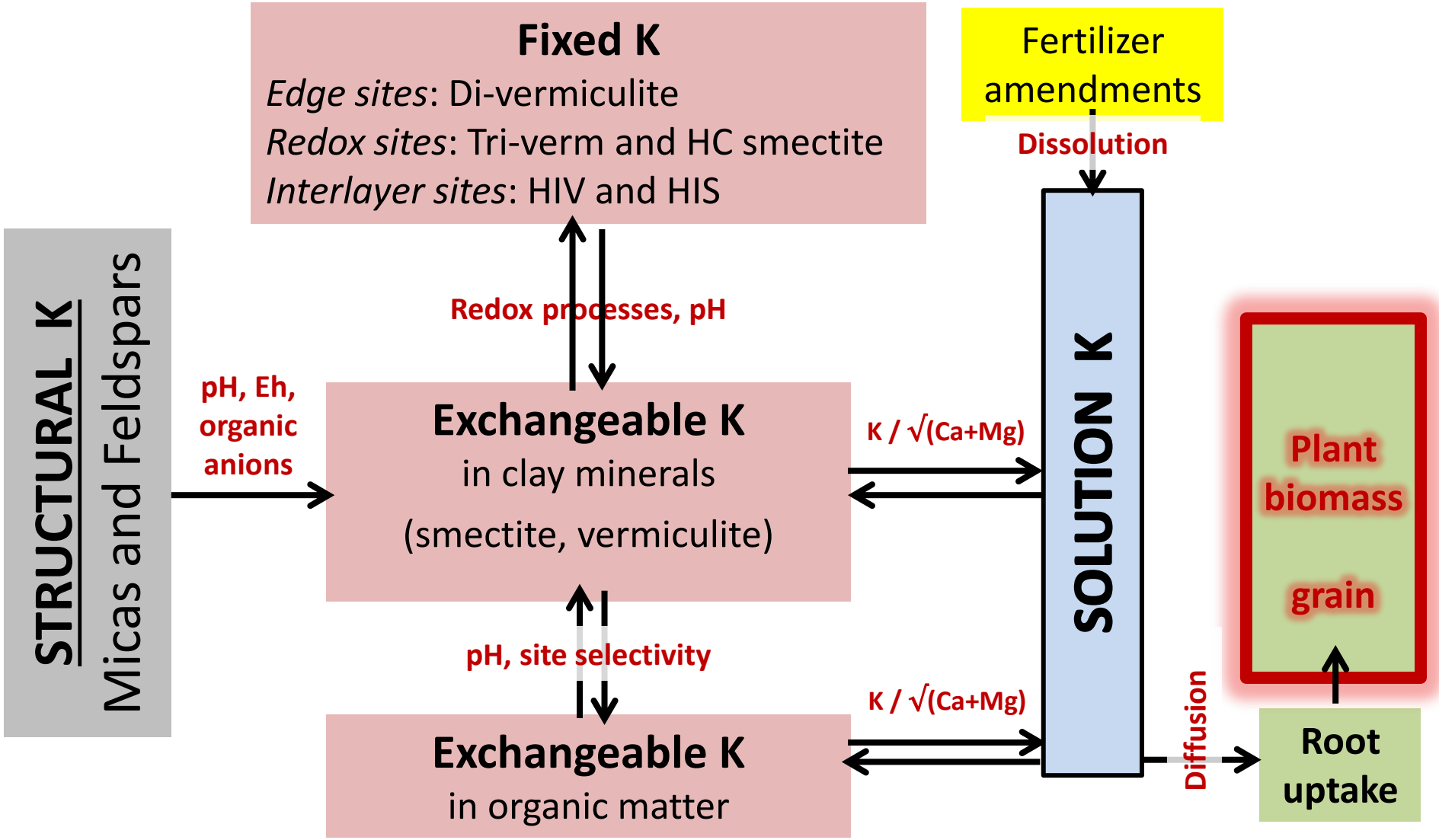
K^+ ion with water molecules clustered around it

http://www.acbrown.com/neuro/Lectures/Mmbr/NrMmbrMode.htm

http://virtual-museum.soils.wisc.edu/kcsa/index.html

Crystal structure of the KcsA potassium channel protein of the bacterium, *Streptomyces lividans.* The image at right was obtained by cloning the channel, synthesizing large quantities, crystalizing the protein, x-diffraction, and mathematical refinement to produce a crystal structure with a resolution of 3.4 Å.

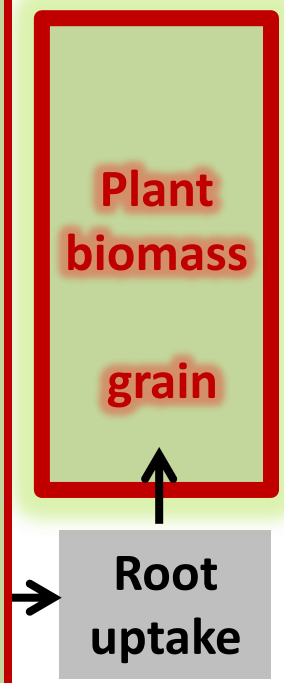
LIFE of K – *The Big Show – Biomass*



LIFE of K – The Big Show – Biomass

K plays vital roles in the lives of plants

- Activates enzymes
- Regulates water movement through stomata
- Maintains charge balance in cells
- Required for protein synthesis
- Improves disease resistance and fiber quality



LIFE of K – *Then it's over – Death*

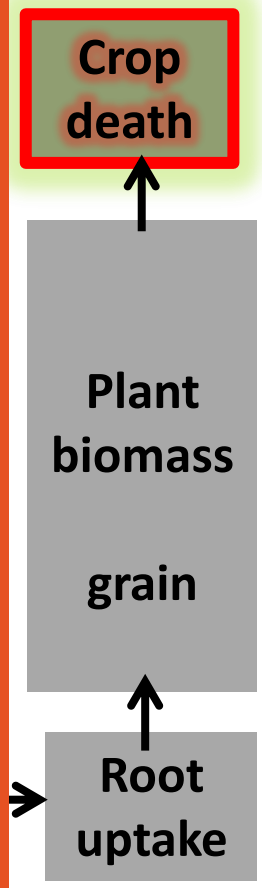
A film by Ingmar Bergman

Cries and whispers

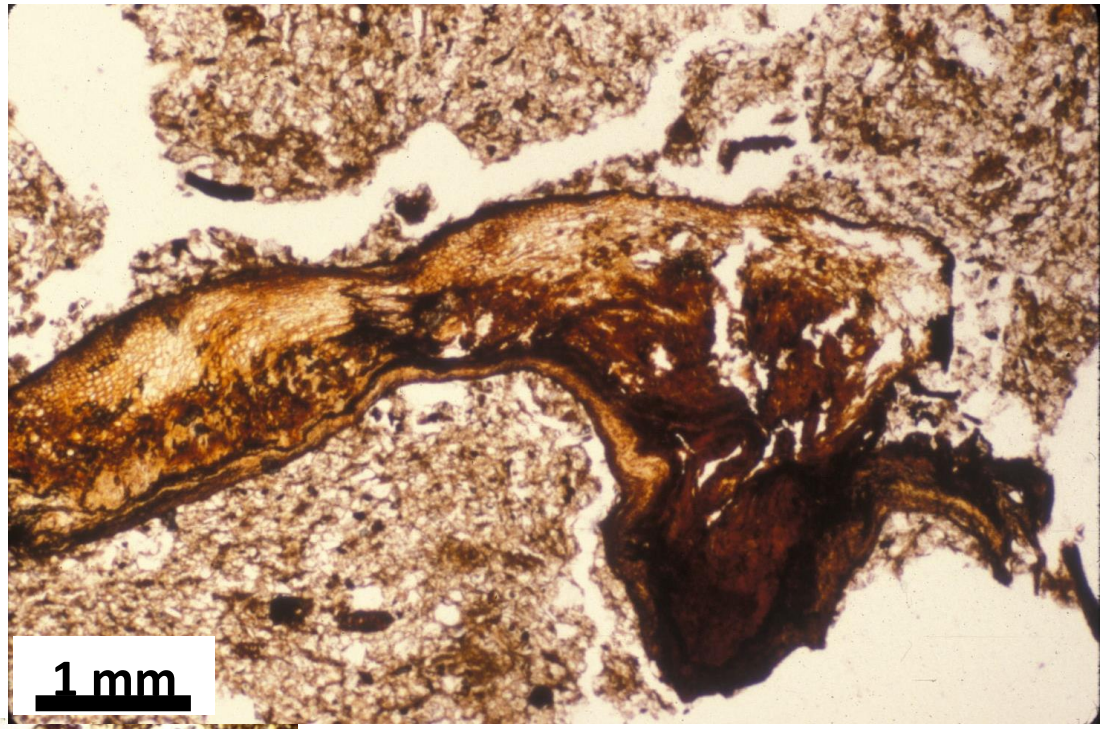
What happens after death?

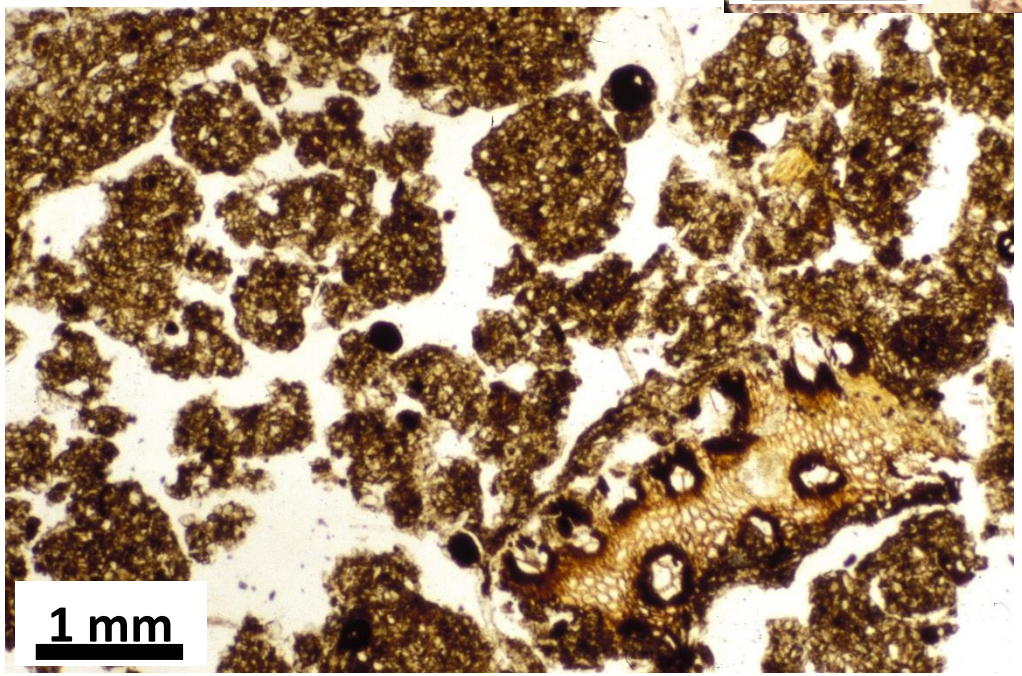
How does one's life and death shape the next generation?

Death is a natural part of life.



Tissue decomposition releases K to the soil solution.

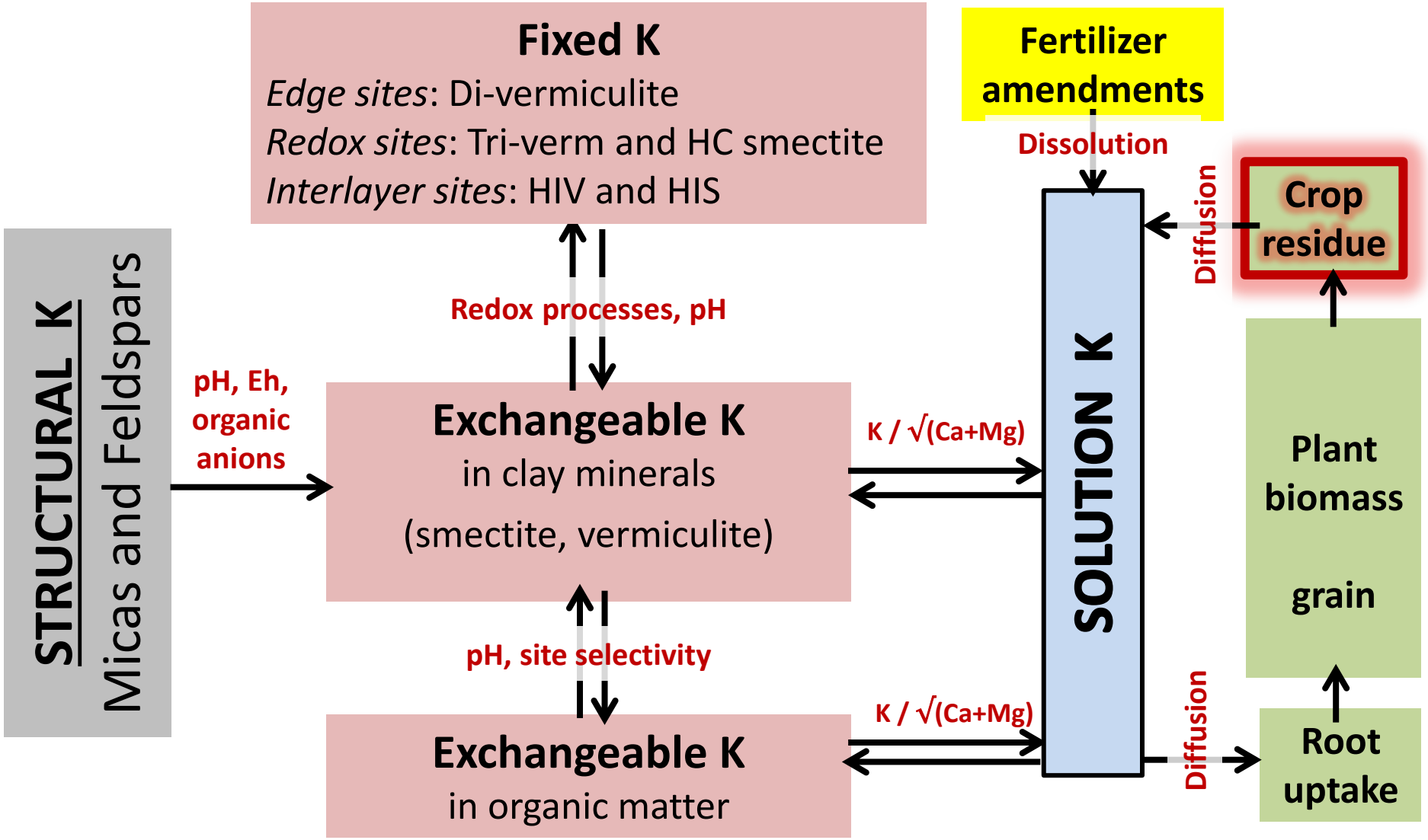




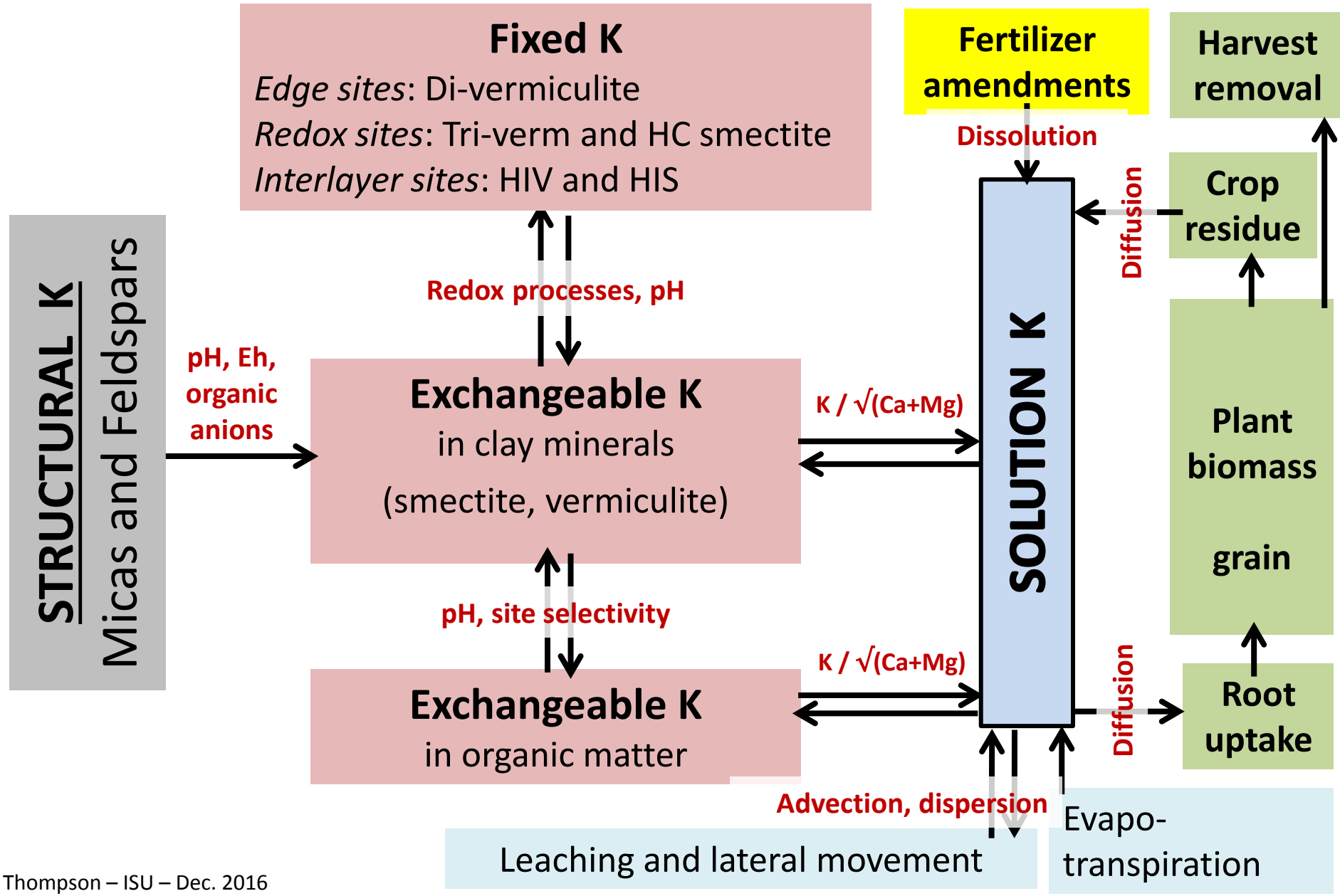
Images by ML Thompson

LIFE of K – *Reincarnation*

LIFE of K – *Then it's over – Death*



LIFE of K – *A beautiful mystery*



Thompson – ISU – Dec. 2016

LIFE of K – *A beautiful mystery*

There is a lot that we do not know about K.

- What is the reality of K forms in soil?
- What is meaningful in the life of K?
- How do the stories we tell one another about K shape our perception of reality?
- How do our stories about K shape the reality of managing K in soils?

LIFE of K – *A beautiful mystery*

There is a lot that we do not know about K.

- What is the reality of K forms in soil? (Do soil tests really measure "exchangeable" and "fixed" K?)
- What is meaningful in the life of K? (Is K fixation significant in a single growing season?)
- How do our stories about K shape our perception of reality? (Under what circumstances could K fixation be permanent?)
- How do our stories about K shape the reality of managing K in soils? (If soil tests don't access temporarily fixed K, will we over-fertilize the soil?)

What can be done to promote the bioavailability of K in soils?

- Keeping the cation exchange capacity high provides an abundance of low-energy exchange sites and surfaces where K^+ ions can be held until plants start to draw on them.
- In most soils, the cation exchange capacity can be increased by increasing soil organic matter and by maintaining soil pH in the range of 6.5 – 7.0.
- Some degree of potassium fixation probably occurs in most soils that contain layer silicate minerals such as smectite, vermiculite, or hydroxy-interlayered forms of smectite and vermiculite.
- **But soil management that promotes good drainage, increases soil organic matter, and maintains pH near neutral is likely to minimize the risks associated with "fixed," slowly available potassium**.