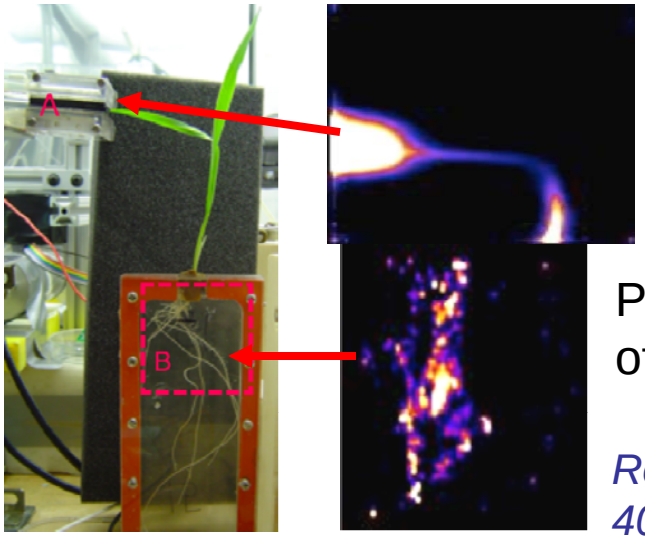
Positron Emission Tomography (PET) Detector Development for Plant Biology

Objectives

- Develop limited angle PET tomography for application in plant biology research
- Apply the technology to studying dynamics of CO_2 transport in plants



Labeling chamber

PET images of ^{11}C

Roots, after 40 minutes

Approach

- Configure two PET systems using scintillator arrays coupled to position sensitive photomultiplier tubes to image ^{11}C
- Evaluate system in $^{11}CO_2$ uptake studies in barley plants, showing transport from leaves to roots

Outcome

- A new technique is available for imaging rapid processes involving carbon in plants
- Potential for many applications in research into optimizing plant productivity for DOE missions in energy and environment

A.G. Weisenberger, et al., 2009 IEEE Nuclear Science Symposium

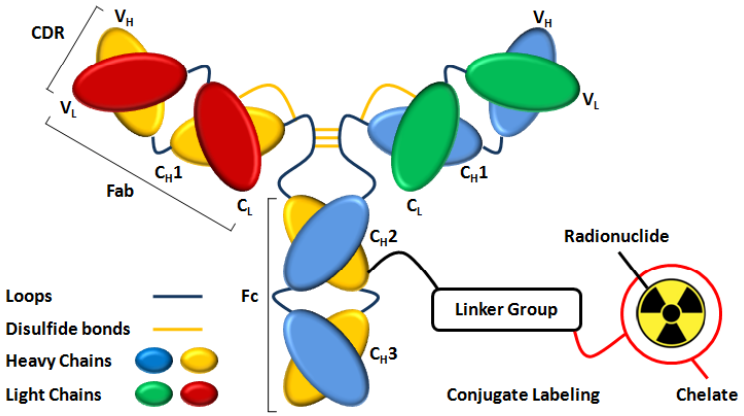
Advancing Research and Training in Radiochemistry

Objective:

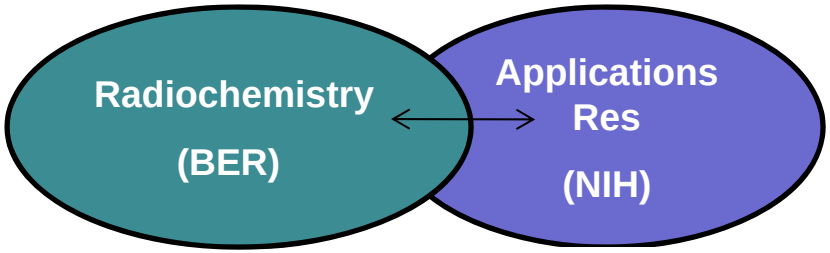
- Train the next generation of scientists in novel and innovative state-of-the-art radiochemistry research

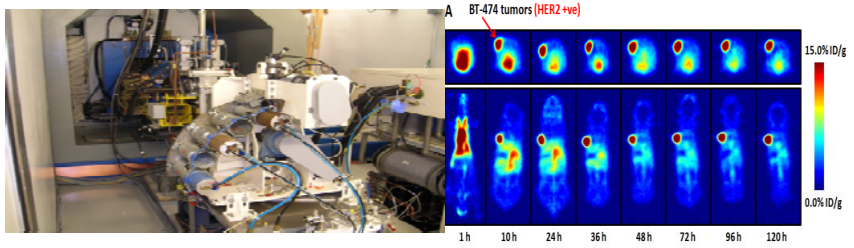
Approach:

^{89}Zr Complexation with Desferrioxamine (DFO)-Conjugated-Protein



Encourage Climate of Collaboration





Results/Impact:

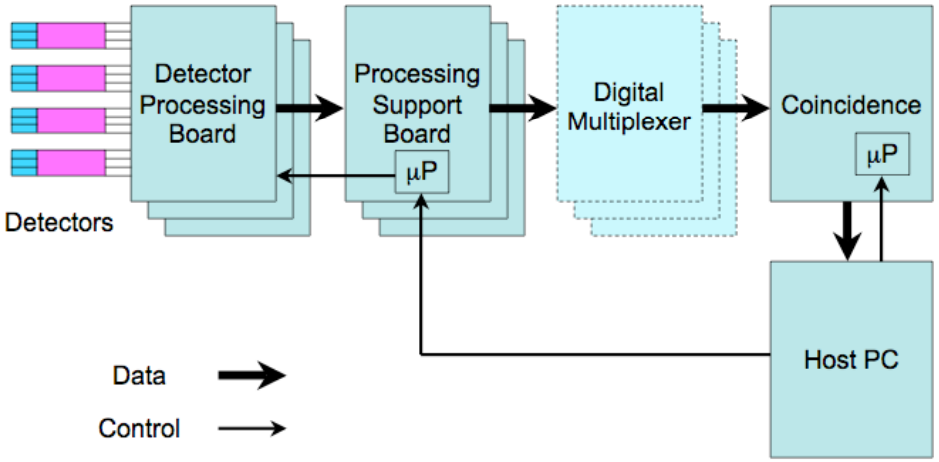
- Contribute to training goals
- Fundamental radiochemistry methodology translated to medical application by synthesis of radiolabeled tracer for non-invasive tumor imaging.

Holland et al., PLoS One, January 25th, 2010

Flexible, High-Performance Electronics for Radiotracer Imaging

Objective:

Design flexible, high-performance electronics that can be used for a wide variety of radiotracer imaging cameras.



Approach:

- Develop OpenPET, a powerful yet flexible electronics system, with software allowing customization.
- Make the information needed to construct these electronics (schematics, circuit board layout, etc.) publicly available

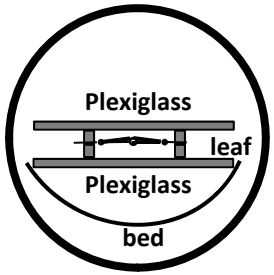
Impact:

- Open-source software and firmware allows multiple research groups to pool resources and speed development.
- Useful for DOE mission needs and the radiation imaging instrumentation community.

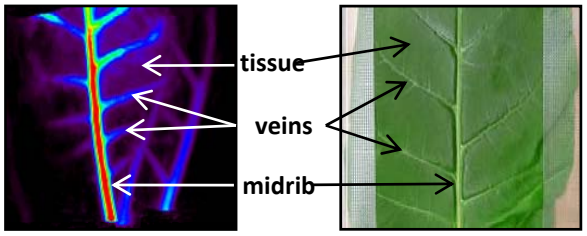
WW Moses et al, *IEEE Trans. Nucl. Sci.* NS-57, (accepted for publication in the September issue), 2010.

New Methods for Quantifying Positron Activity In Plants using PET

Objective: Develop quantitative methods for determining radiotracer concentration in plants.



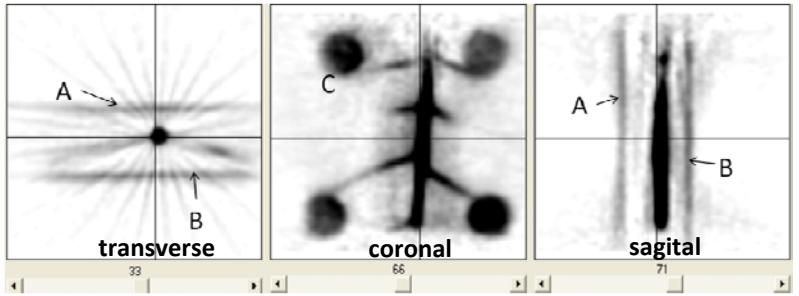
PET gantry



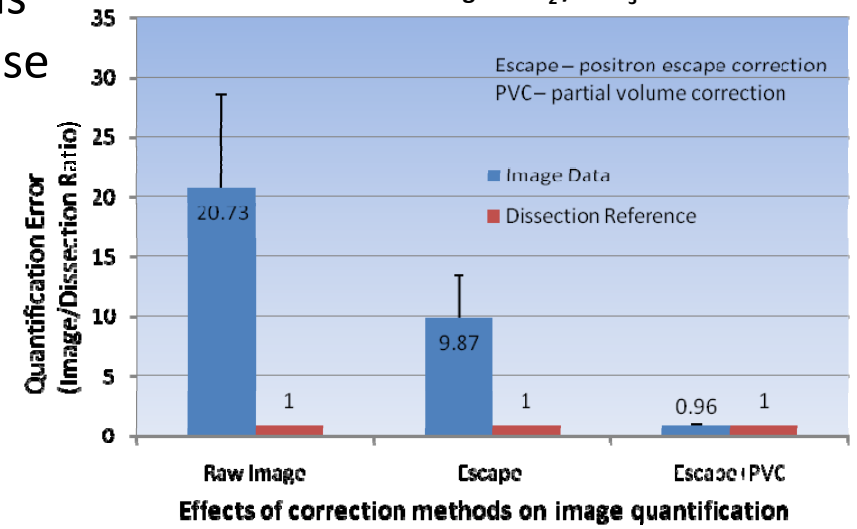
microPET image ^{18}F- photograph

Approach:

- Characterize the two major sources of quantification error in PET imaging of leaves: escaping positrons from tissue and partial-volume averaging.
- Develop new image data correction methods for quantifying leaf activity and compare these results to "true" activity determinations derived using dissection.



microPET image $^{13}NO_2^-/^{13}NO_3^-$



Effects of correction methods on image quantification

Impact:

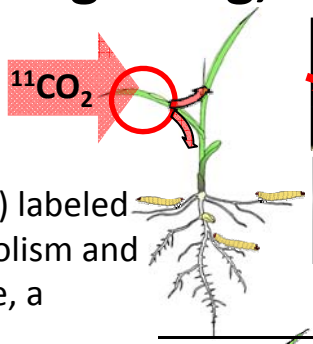
Enables study of dynamic physiological processes in plants using PET to understand plant responses in active ecosystems.

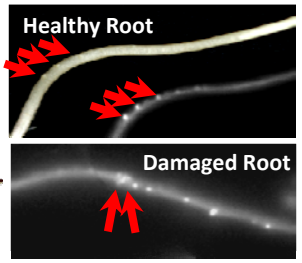
Alexoff D et al, S. *Nuclear Medicine and Biology* Online publication 28 October 2010.

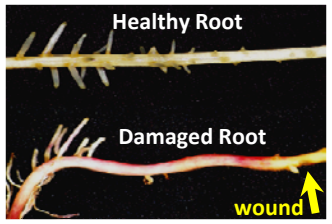
Crop lodging caused by rootworm damage

Carbon-11 radiosynthesis of auxin and its biosynthetic precursors to probe root signaling, metabolism and development

Objective: To develop and apply carbon-11 ($t_{1/2}$: 20.4 min) labeled radiotracers to measure changes in auxin signaling, metabolism and growth when plants were challenged by rootworm damage, a potential threat to future bioenergy feedstocks.



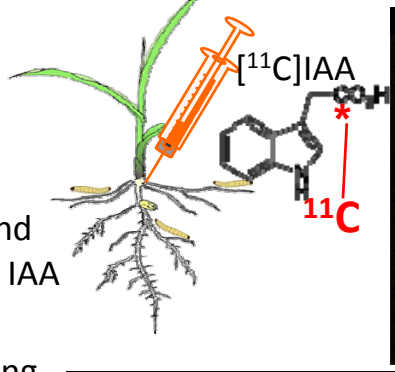


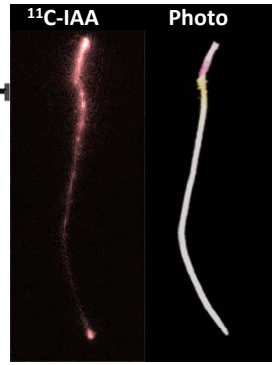


High metabolic activity coincides with developing lateral root primordia.

Approach:

- $^{11}CO_2$ was administered to leaves as a tracer of sink metabolic activity, and distribution measured by autoradiography.
- A rapid new synthesis of [^{11}C]indole-3-acetic acid (auxin, IAA) and [^{11}C]indole-3-acetonitrile ([^{11}C]IAN), a biosynthetic precursor of IAA from [^{11}C]cyanide was developed.
- [^{11}C]IAA was administered to roots as a tracer of auxin patterning, and [^{11}C]IAN was administered to damaged and healthy roots and used to measure biosynthetic conversion of ^{11}C-IAN to ^{11}C-IAA .

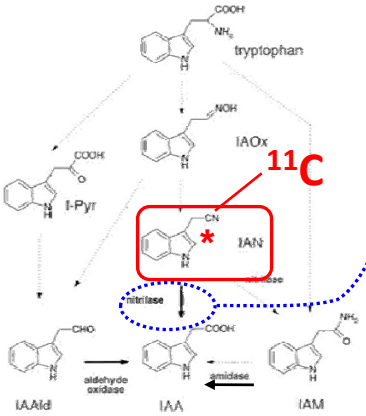


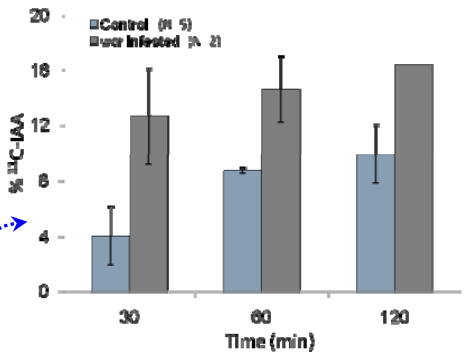


Sites of auxin accumulation coincide with lateral root primordia & the root apical meristem.

Impact:

- Development of a rapid synthesis of [^{11}C]IAA and IAN enables a study of the links between hormone signaling, metabolism and root development in response to environmental and other challenges including root herbivory.





Damaged roots have higher IAA biosynthetic rates.

Radiosynthesis of C-11 labeled auxin (3-indolyl[1-11C]acetic acid) and its derivatives from gramine. Reid, A. E., Kim, S.W., Seiner, B., Fowler, F. W., Hooker, J., Ferrieri, R., Babst, B. A., Fowler, J. S. *Journal of Labelled Compounds and Radiopharmaceuticals* (2011) 54:433-437.