RESEARCH OPPORTUNITIES IN PLANT ECOLOGY, PHYSIOLOGY AND BIOCHEMISTRY USING STABLE ISOTOPE TECHNIQUES AT THE NATURAL ABUNDANCE LEVEL

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GLOSSARY OF TERMS

ammonium	NH_4^+.
anaplerotic	pertaining to biochemical pathways of living organisms and indicating additions to a process from within the organisms, from another pathway. A kind of internal "topping-up" mechanism.
atom percent	the abundance of a heavy isotope as a percentage of the sum of all isotopes of that element.
biogeochemical	the relation of the interaction of biological, geological and chemical processes.
biochemical reactions	chemical reactions mediated by living organisms.
biophage	literally life-eater, meaning an organism which eats another organism, as in plant pests.
bundle sheath	a bundle of cells surrounding the vascular strands ("plumbing") of a leaf.
C	the element carbon.
C_3 plants	so classified because the first product of photosynthesis is a compound having 3 carbon atoms.
C_4 plants	so classified because the first product of photosynthesis is a 4-carbon compound. There are additionally plants which possess incomplete versions of C_4 metabolism and are called C_3-C_4 intermediates.
CAM plants	Crassulacean acid metabolism: much like C_4 plants except that they have a day-night rhythm in which they fix carbon at night as acids and refix it during the day as sugars and starches.
catalyst	increases the rate of a chemical reaction but remains unchanged.
closed systems	a system is closed if it has no external inputs or outputs. It is self-contained.
delta, δ	a symbol used to denote the most usual measurement of natural abundances of stable isotopes.
deuterium	the second heaviest isotope of hydrogen. Symbol ^2H or D.

di-nitrogen	N_2 gas. This is the commonest form of nitrogen. About 78% of the atmosphere is di-nitrogen gas.
discrimination	when the reaction rate of one isotope of an element is greater than that of the other isotopes, we say that there has been an isotopic discrimination. For example, if the beginning ratio of atmospheric CO_2 is -8‰, and C as it occurs subsequently as starch inside a leaf is -28‰, then a discrimination of 20‰ has occurred. (see fractionation).
enriched	when a isotopic discrimination leaves behind more of the heavy isotope than the light one, we say that the substance is enriched. Substances are always enriched or depleted relative to the heavy isotope.
enzyme	a biological catalyst which participates in biochemical reactions and helps them to proceed, but is left unchanged by the process.
flux	the rate of change of mass per unit area per unit time such as grams per m^2 per day.
equilibrium reaction	a chemical reaction in which the beginning substances never completely disappear and the reaction never goes to completion. Instead an "equilibrium" or "agreement" is concluded in which a set amount of the substances will be in a given form at any one time. Whether products or reactants predominate can be influenced by external factors such as temperature or pH.
fractionation	an isotope fractionation occurs when a physical or chemical process results in an isotopic enrichment on depletion.
groundwater	water in the permanently saturated zone of rocks and sediments.
H	the element, hydrogen. Hydrogen has three isotopes, protium (^1H), deuterium (^2H), and tritium (^3H). Protium and deuterium are stable isotopes; tritium is radioactive. δD and $\delta^{2/1}H$ mean the same thing.
isotope signature	the isotope ratios or δ-values measured in a sample. The net isotope signal left in a substance after some reaction or process has occurred.
isotope ratio	the amount of heavy isotope divided by the amount of light isotope.
isotopes	atoms having the same atomic number, but different atomic masses.
kinetic reactions	chemical or physical reactions which go to completion.
mass	an intrinsic property of matter. Measured as weight, which is

actually the effect of gravity on mass.

memory effects — a mass spectrometer may be contaminated by chemicals so that it does not give a true reading.

N — the element nitrogen.

natural abundance — the naturally occurring ratios of heavy to light isotopes.

nitrate — NO_3^-.

nucleus, atomic — the centre of an atom, consisting chiefly of protons and neutrons.

nutrient — any of a number of substances which are essential for the life and growth of organisms.

‰ — parts per thousand.

O — the element oxygen.

open system — a system with external inputs, outputs or both.

organisms — complex living systems which exhibit growth, reproduction and response to stimuli, e.g. plants, animals, bacteria.

pollutants — substances which are in sufficient excess to become a nuisance or a hazard.

radioactive isotopes — isotopes which spontaneously emit radiation.

S — the element sulfur.

sources and sinks — a term especially used in food web and pollution research. It describes the pathway from the source of a substance to its "final" destination in nature.

stable isotopes — isotopes that do not undergo radioactive decay.

transparent — as used in isotope work, this means that a given process does not affect the isotope ratio.

EXECUTIVE SUMMARY

This initiative will establish in Scotland a world–centre for a crucially important new area of research, raising the global profile of British science at a very modest price. It will create a magnet for scientists, students, and industrial development which will bring large amounts of external funding to Tayside and fly Britain's scientific flag from a very high mast. This is one opportunity we can grasp, to develop to full economic and scientific fruition the skills and potential nurtured and funded with great effort thus far. This initiative will establish a multi–disciplinary group to investigate non–radioactive stable isotopes at the natural abundance level in key biological systems.

The use of natural abundance levels of stable isotopes are the way forward in all of the life sciences, a benign, non–intrusive way to use naturally occurring signals to describe processes, to source and monitor pollution, to model systems, and to select crops, as well as quickly assess the results of genetic manipulations. This approach has now been used at every level from genetic and molecular to global (climate change). It has the unique ability to coalesce the particular and the general, to bring together knowledge which is reductionist and holistic. It can be used to assist in statutory enforcement and basic research, to identify polluters and develop better conservation management, even to identify some kinds of food contamination. Until recently, this field was limited by analytical drawbacks. A very few major breakthroughs have changed this. Happily, some of the pioneering innovators are here in Tayside. Because of a unique concurrence of expertise, basic instrumentation, and groundwork already accomplished, the SCRI is uniquely poised to make Scotland the world centre for stable isotope research at the natural abundance level.

World–wide, natural abundance work is fragmented, with major researchers in Japan, Australia and the USA, but each working on a small aspect or with only one or two isotopes. The situation is similar in Britain. There are several major workers in Britain, some of them world–class theoreticians, but they too are isolated in approach and organisation; additionally, the British profile is low, largely unrecognised in the international scientific community at the moment.

The SCRI can, at a relatively low cost, establish the world's only multi–disciplinary centre for this work; this is the right time to proceed; the need is universally felt among scientists. Professor Ehleringer of Utah recently wrote that "natural abundances of stable isotopes have exploded into the world of ecology." Stable isotopes are similarly important in understanding the details of biochemistry. The time is ripe; the crucial people and base are here at the SCRI and nowhere else in the Kingdom; it would be a tragedy for Britain to lose this advantage in establishing a global centre for this exciting new work which crowns the best of the British scientific base, involving chemistry, mathematics, physics, biology, biochemistry, ecology, marine sciences and agriculture, with a very modest investment.

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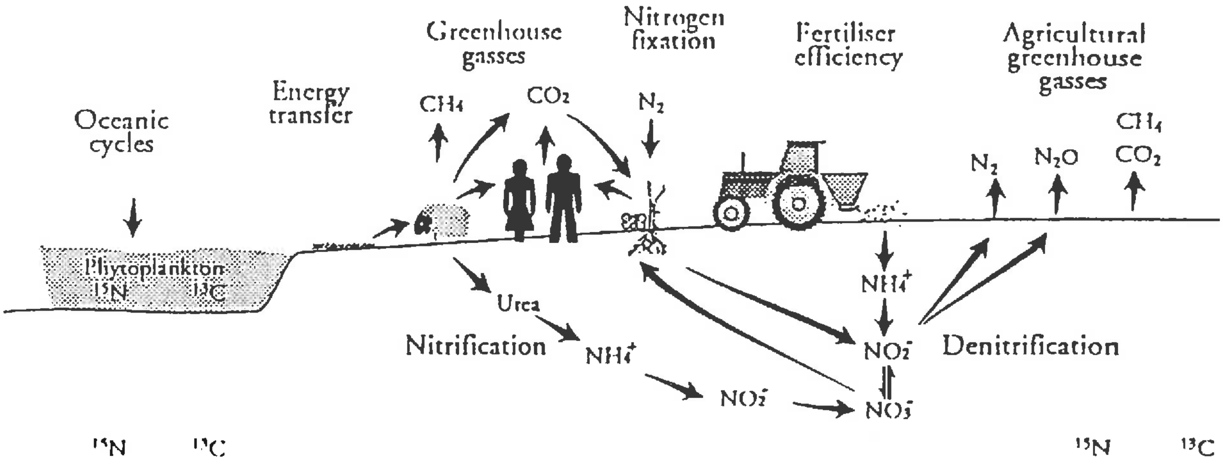

Figure 1. These are a few of the important processes which can be identified and assessed using natural abundances of stable isotopes. The natural isotope markers for all of the processes shown here are heavy nitrogen and heavy carbon, denoted ^{15}N and ^{13}C. From left to right, one-celled plants (phytoplankton) use nitrogen (N) and carbon (C). Grazing animals excrete organic nitrogen as urea. In the soil, the urea is chemically and microbially changed to ammonium (NH_4^+), then nitrite (NO_2^-), then nitrate (NO_3^-). Nitrate (NO_3^-) can then be used by plants or denitrified as new chemical forms; di-nitrogen gas (N_2) or nitrous oxide (N_20). Soil ammonium and nitrate can also arise from excess fertilizer application or from natural fixation of N_2 by plants.