Bio-energetics

No particularly sophisticated techniques had been used to elucidate the essential elements of the two complementary mechanisms of photosynthesis and respiration which are engaged in the production of the energy carrier ATP and which constitute the basis of life. Nevertheless these techniques offer new means of revealing details of some of the still unknown stages in these processes. The pulsed laser had already made possible the use of precise flash illumination of biological specimens, and had helped to improve the signal/noise ratio in the requisite spectographic analyses.

The processes involved in the production of ATP by respiration are the reverse of those in photosynthesis. The active membrane in which the energy of sunlight is converted into chemical energy — the thylakoid — is about 40 Å thick and contains several hundred pigment cells (chlorophyll). The energy transfer from the solar input is accomplished by vectorial transport across this membrane of electrons from H_2O molecules. A potential gradient develops and induces a flow of protons across the membrane into the enzyme responsible for the production of the energy-rich ATP. There is therefore also a pH gradient across the membrane. The mechanism for splitting the H_2O molecule and other fine details are still unknown but measurements have confirmed the basic findings of vectorial electron transfer, proton into enzyme migration and the need for the co-operation of two chlorophyll centres. It has been possible to induce part of such processes in membrane enclosed vesicles by the external application of a voltage and exposure to sunlight. From thermodynamic considerations the efficiency of such a photosynthesis process could reach 70%, but in nature, the overall efficiency amounts to a mere fraction of this. Energy production is only an incidental part in the grand scheme of life and the survival of the species.

Simon Newman

Heavy Ions

In modern physics, theories and models often make predictions that cannot be tested because they require conditions that are far out of experimental reach. This is especially true for nuclear physics. "Classical" nuclear physics usually is dealing with nuclear matter near its ground state: the excitation energies are normally quite low, the angular momenta are small and the densities are about the equilibrium density. For these conditions there exist quite successful models that are able to describe the gross structures (e.g. the liquid drop model), but there are also very elaborate models predicting details like the nuclear deformation and transition probabilities (e.g. the interacting boson (1B) model).

These more sophisticated models have been tested against the available data, where absolute transition matrix elements are usually known for not more than three to five nuclear levels. The deformation is usually only known for the ground-state in odd nuclei and for the first 2^+ state in even nuclei. Thus the comparison between experiment and nuclear models has had a relatively weak basis, especially as the significance of each data point is questionable because of the great experimental difficulties. Intrinsic and experimental difficulties limit the accuracy to such an extent that the deformation of excited states can be determinated to only about 10%, whereas for a transition matrix element ± 1% is an excellent result.

With the newly established powerful particle accelerators, exciting new classes of experiments can be performed and it was natural that topics covered mainly either experiments performed at these machines or new theoretical approaches to the experimental data yielded there. To broaden the basis of experimental data, it is promising to investigate very high energetic nuclear collisions or collisions between very heavy nuclei. The first type of experiment can be performed at Berkeley or Dubna. The machine at Dubna e.g. accelerates light nuclei such as ^{16}O up to an energy of 5 MeV/nucleon. In reactions between such high energetic projectiles and target nuclei, densities of several times the normal density are reached. For these conditions such spectacular things like phase transitions and pion condensation are expected to occur. Even the explosion of the projectile inside the target nucleus has been observed. Understanding the physics under such extreme conditions seems to be only at the beginning. Nevertheless a lot of phenomena can be explained e.g. by a hydrodynamical model, that fits the experimental data surprisingly well, considering the simplicity of the modelling.

For the second class of experiments a new powerful tool is given by the UNILAC heavy ion accelerator in Darmstadt. This machine accelerates any known stable ion to energies well above the Coulomb barrier even when uranium is the target, (5 to 6 MeV/nucleon). It should be emphasised also that this facility is not only used for nuclear physics research. The scale of experiments stretches from atomic physics to elementary particle physics, from quantum electrodynamics to the search for super-heavy elements. Using the UNILAC in nuclear physics it is now feasible for the first time to study the lead-uranium system slightly below the Coulomb barrier—performing multiple Coulomb excitation (MCE) experiments – or even above the barrier.

The great advantage of lead as a projectile lies not only in the heightened excitation probability, that is dependent on the charge number of the projectile but especially also on the rise of intrinsic angular momentum that can be transferred. In a classical picture, the angular momentum is proportional to the nuclear deformation of the target nucleus and the charge of the projectile. Quantum calculations yield essentially the same result but give only 80 to 90% of the classical value. For Pb shot on U, a maximum value of $34\hbar$ is expected in an MCE experiment. Unfortunately not only the desired effects are increased but a strong Doppler broadening due to the high recoil energy goes against the use of heavy ions as projectiles. The broadening is governed by the angular distribution of the target nuclei recoiling into vacuo,