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Optical effects help magnetic imaging

MRI scans may get more hi-tech, says S.Ananthanarayanan.

MRI, or Magnetic Resonance Imaging, is a method of non-invasive, medical investigation of the interior of the body, which depends on NMR, or Nuclear Magnetic Resonance, an advanced kind of scientific effect being used in medicine. The journal, ***Nature*** has reported developments that make this diagnostic tool more powerful.

Scanning and structure

We may know that substances exist as molecules, which are the combination of different atoms of the elements that make up the molecule. One way of investigating atoms and molecules is with X-Rays. Here, the atoms in a crystal act as centres to scatter X Rays. As the dimensions of the crystals are about the same as the wavelength of X-Rays, scattering causes interference of the scattered and original waves, something like the patterns formed when waves move towards and away from a shoreline. The interference pattern then reveals much about the crystal structure.

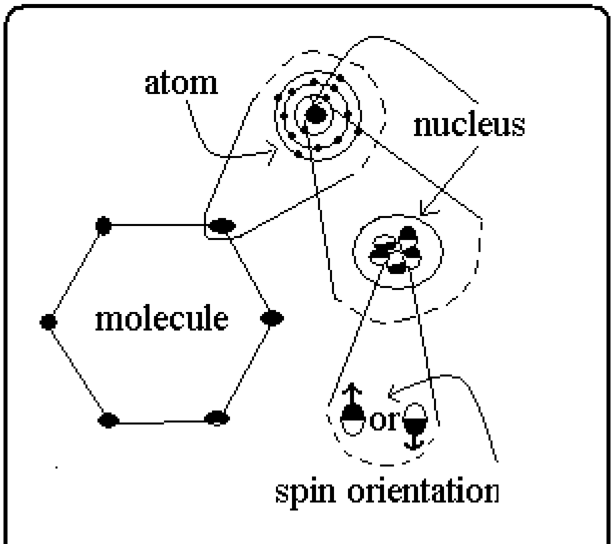
In medicine too, shadows of X-Rays passed through the body are studied at different ‘slices’ of the body. Putting the information together, with the help of computers can yield a detailed picture of body internals, a method popular as the CAT scan.

Another method of investigating molecular structure is by looking for the frequencies of light, usually in the Infra Red region, that the molecules absorb. Specific frequencies indicate specific pairs of atoms that occur in the molecule, for example, C=O, of carbon and oxygen with a double bond, or C≡N, which is carbon and nitrogen, with a triple bond. This method does not have a direct medical application, and is more a laboratory procedure to identify the presence of molecular groups.

NMR

The nuclei of atoms also indicate the nature of the molecules in with they occur. This is with the help of a specific nuclear property, which is affected by the molecular environment.

The nucleus is the tiny, massive centre of atoms, something like the earth in the earth-moon system. But the nucleus has a positive electric charge and it keeps surrounding electrons in their orbits with the help of electric attraction, just like the earth keeps the moon in place with the help of gravity.



Molecules and nuclear spin

Apart from being charged, nuclear particles also have a property called 'spin', so called because it gives the particles an angular momentum, like a spinning top. And as the particles are electrically charged, spin results in magnetic effects and nuclei behave like tiny magnets.

Now, in the presence of a magnetic field, these little magnets align themselves in different directions, each with a different energy, and the nucleus can absorb of emit radiation by making transitions from one energy state to another. Thus, when radiation (light) of a gradually changing frequency is passed through a sample of the nuclei, the radiation emerging from the other side shows a sharp drop just at the frequency that corresponds to a nuclear transition.

Both how strong is the dip as well as the exact frequency depend to a marked degree on the electric effects of the surrounding electrons and the nearby atoms in the molecule of which the atom is a part. This frequency and the strength of the dip are exactly measurable and can act as specific 'fingerprints' of molecules or portions of molecules.

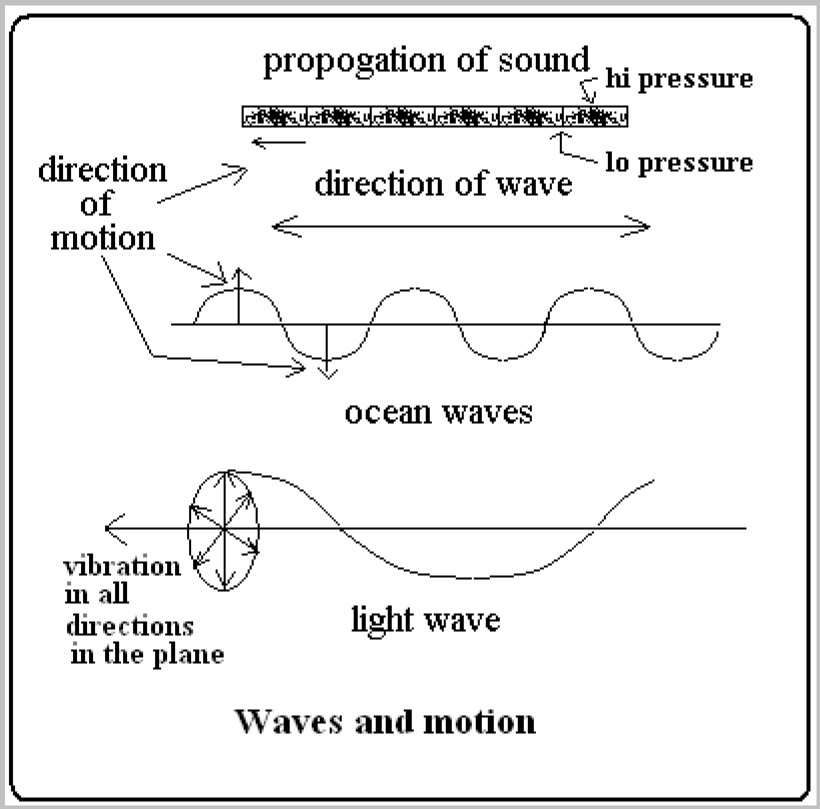
Spectroscopy and Imaging

The pattern of absorption can be charted, tabulated and processed, to give a detailed picture of the molecules in which the nuclei are located. Getting the 'NMR spectrum' can then become a powerful tool for research and chemical analysis. In medicine, NMR is used to locate specific tissue types and aid for diagnosis, better known as Magnetic Resonance Imaging, or MRI.

But as an investigation tool, NMR has the limitation that it only identifies the presence of molecules, it cannot display the layout of the atoms in the molecule, or the group of molecules – at least without complex stratagems.

Faraday effect

This is where the development reported in ***Nature*** this week comes in. The Faraday effect is that magnetic fields can rotate the plane of polarization of light. Light waves consist of vibrations not along the direction of motion, like in sound waves, but at right angles, like ocean waves. But unlike ocean waves, which move ‘up-down’, light waves can move in any direction in the plane perpendicular to the direction of motion (see pic). If the waves are restricted to only one such direction, the waves are said to be polarized and the plane is direction is called the ‘plane of polarisation’.



Now, if such ‘plane polarised’ light is shone on nuclei, the magnetic effects in the nuclei having the transitions will affect the plane of polarization of the beam. Watching the changes in polarization then reveal details of the transitions and hence of the molecule. The effect is found to be so sensitive that the limitations of locating spatial spread of NMR nuclei are overcome.