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## Particle if you see, wave if you don't Getting to know the path that electrons take helps show what happens next, says **s ananthanarayanan**

which says energy is transferred in discrete "lumps", and the Theory of Relativity, which says matter and energy are equivalent, leads to particles being endowed with wave proper-ties and a scheme of calculation, called quantum mechanics, which deals with both the manifestations of energy at the same time. But the particles at correspond to waves that we can

deal with are so minute, or the waves associated with real life particles are of such short wavelength, that prac-tically observing wave-particle duality has been out of reach. A group of scientists from the So-leil synchrotron particle accelerator in France, with others from Sweden

and Japan, describe in the journal *Nature photonics* a method where the two atoms in an oxygen molecule are used as a truly small dimension pair of "scatterers". The action starts when the molecule, on being excited by X-rays, de-excites by emission of an electron from one of the oxygen atoms. The electron emitted behaves

Before the molecule dissociates, the atoms recoil togethe

After dissociation, the atoms move apart when the electron

is emitted, a case where Young's slits can move separately

like Youna's slits being rigidly connected

come from either atom, but like a particle if the atom from which it came could, in principle, be identified. This result casts the die in fav our of one side in a celebrated debate between Albert Einstein and Niels Bhor, one of the fathers of quantum mechanics. The distinguishing quality of

wave-like behaviour is that when wa-ves meet they can either add and grow stronger or they can cancel each other out. Light that strikes a pair of slits in a barrier would give rise to a pair of waves arising at each slit. The waves from these two sources striking a screen further on would then create a pattern, called an interference pattern, of bright and dark lines or spots at places where they add or cancel.

This is the historic Young's double *slit experiment*, which laid the basis of the wave theory of light. But now we know that light consists, in fact, of discrete lumps or particles called *photons*. These photons could not have passed through both the

slits, as we have imagined, but should have passed through one or the other, and there should be no interference pat-But there is interference nev-

ertheless, because quantum mechanics holds that all things, so long as they are left alone, are in all their possible states of being. This is to say that the photon, if it is left alone, passes through both the slits at the same time, resulting in interference. But if there were a measurement, or one of the slits were closed, then the photon passes only through the slit where it was measured, or the slit that was open, and there is

VALUABLE FRAGMENTS



recoil accurately would introduce uncertainty in the position of the slit. This apart, the mass of any real Einstein never quite accepted the statistical, or probabilistic method of quantum mechanics, which considered particles to have a spread, or un-certainty of position. In the course of slit in a material screen would make the event of the recoil on the passing his discussions on wave-particle duof the photon impossible to measure And if more energetic light of very short wavelength, or a beam of elec-trons were used, then the slits would ality with Bhor, Einstein proposed an imaginary experiment, called a thought experiment, or, in German, a gedankenexperiment, which would have to be too close together to be practical. And for these and other reasons, experimental verification show a discrepancy in the idea of duality. Young's two-slit experiment is considered to work for light behas not been possible and the ques cause it is not possible to know which slit the photon passed throution remains in the *gedanken*. But the team working at the Soleil synchrotron have found a way to pergh. Einstein proposed that if the slits were not fixed in the screen, but could move, then the act of the phoform the experiment at the molecu-lar level, using the two atoms in oxy ton passing through one of the other gen molecules to act as the pair of slits would be detectable in princi-

slits. It is not light that is routed through the atoms, but the experiple, by the recoil of the affected slit. And as the path the photon took could, hence, be marked by the rement is with electrons that are emitted from one of the pair of atoms. If which atom the electron came from coil, there should not have been any is uncertain, then there would be an The theoretical objection to this interference pattern where the elec that an act of measuring the

tron is detected But if which atom

AN ANALYSIS SHOWS THE FAMOUS SKELETON WAS OF 'A VERY SENIOR AND PROMINENT MEMBER OF SOCIETY', WRITES TOM BAWDEN

quarter of a century after his skeleton was unearthed in a A Sussex field, "Racton Man" has finally revealed his secrets. And it turns out he was quite the Bronze Age hero. Scientific analysis of his bones has revealed he was probably a tribal leader with a giant stature — and may have been killed in combat. Not only did he tower over his fellow men, coming in at six feet tall, h also outlived most of them by a considerable margin, managing to sur vive for at least 45 years before finally meeting his death through a sword slash near his elbow. His weapon of choice was also remarkable — a bron-ze dagger that, at 4,200 years of age, represented the ultimate cutting-edge

researchers say. "The fact that this man had a bronze dagger would have been incre-dibly rare then. This would have been right at the start of the introduction

of this type of technology," said James Kenny, the Chichester council archaeologist who discovered the skeleton in the West Sussex hamlet of Racton back in 1989 "He would have been a very promi-



the electron came from was known, then there would be no interference. Neutral oxygen molecules are first excited by soft X-rays from the syn-chrotron radiation. Absorption of Xrays disturbs the electronic linkag of the atoms, which begin to rapidly move apart. The system also de-ex cites by the emission of an electron. If this emission happens before the atoms separate, the recoil of the electron ejected is shared by the whole molecule and which atom the electron came from cannot be made out. But if the emission happens after the atoms separate, then only the atom

concerned recoils. Sensitive measurement of the momenta of the different particles that issue from the interaction ena-bles finding out whether the recoil has been shared or not, and thus whether the electron came from an

identified atom or otherwise. The pattern of detection of the emitted electrons consistently showed an interference pattern every time the emission was from the mol ecule before the atoms separated and the interference disappeared when the emission was from a free oxygen ion, after the atoms had separated. The arrangement, thus, exact ly mimics Young's slits experiment with light, and also allows for the "movable slit" of the gedankenexper *iment* of 80 years ago, in the form of the free atom that recoils away from the other atom when the emission of the electron is after the molecule breaks up. When this happens, there is no interference. But if the emission happens earlier, then both atoms recoil together and they can not be made apart, there is interference, with the electron behaving in a

"wave-like" fashion THE WRITER CAN BE CONTACTED AT

Bronze Age superman

a far harder and more beautiful alloy. Despite being uncharacteristically strong, there are signs that Racton Man's tough life was catching up with him by the end. Analysis of his bones revealed signs of spinal degeneration, which are thought to be age related, while he was also suffering from a chronic sinus infection and arthritis. A severe cut has been found - "at or near the time of death" — to the upper-right arm bone, close to the elbow, and there is no sign that this had healed. This is consistent with the arm being raised, elbow bent above the head, to protect it from a blow

from a weapon. Racton Man is thought to have died between 2300- 2150 BC. "To think we can discover such detail about a man who died more than 4,000 years ago, while learning more about the coun try's history, is just incredible," said Myles Cullen of Chichester District Council.

Kenny said the long wait to discover Racton Man's identity was down to a lack of funding. Back in the 1980s, techniques such as carbon dating were much more expensive and less effective than they are today. As a result, the skeleton languished in the Novium Museum storage facility in

Chichester for years. Kenny had all but forgotten about the skeleton when he mentioned it two years ago to Dr Needham. The pair went to look at the skeleton and dagger in the museum store. They secured funding from the South Downs tional Park and assembled a team of experts to

and dagger are now on display at the museum.



PLUS POINTS

Microflora for hire

In the midst of his graduate training at the University of Illinois at Urbana-Champaign, Dylan Dodd spent a good chunk of time examining bacteria from cow stomachs. He characterised a suite of enzymes that allow one species, *Prevotella bryantii*, to break down the polysaccharide xylan, a major constituent of plant cell walls. Along with his adviser, microbiologist and animal scientist Isaac Cann. Dodd was "prospecting" for enzymes that might be conscripted for biofuel production. Searching for related enzymes in other organisms, he uncovered genes from several specie of Bacteroides - common microbial inhabitants of the human colon. Even though *Bacteroides* and *Prevotella* belong to the same phylum, the

"Although they both (inhabit) gastrointestinal environments, they are rather different." In the cow rumen, some microbes break down cellulose fiber into sugars, and others ferment the sugars to short-chain fatty acids, which then move on to the true stomach. In the human digestive tract, sugars aren't even released from plant polysaccharides until they pass hrough the stomach and reach the

intestine. "Since I was an MD-PhD student, I was very interested in trying to find out what the clinical importance of this could be," said Dodd, who is now a university School of Medicine. "There were very few studies on dietary fiber degradation by (human) gut bacteria at least at the molecular level."
A decidedly non-clinical motive is helping to drive new interest in this

process: the quest to produce biofuels. Biochemists have scoured the kingdoms of life for sources of enzymes that can break apart bonds in the polysaccharide chains that make up plant cell walls. Wood degrading fungi and termite-gut microbes have proved fruitful sources, but mammals' microflora have also drawn attention: scientists at Tulane University and Mississippi State University have even investigated enzymes from zebra and panda guts, respectively. The utility of human microflora-derived enzymes for biofuels is a new and still open question — but the value of understanding how we digest plant

matter is indisputable. With help from microbes in our intestines, we can derive nutrition from hemicelluloses: human microflora digest about 70 pe rcent of xylan, a major component of cereal grains and the second most common plant polysaccharide after cellulose. But precisely how our microflora achieve this breakdown is still largely a mystery.

MOLLY SHARLACH/THE SCIENTIST

Sorting made simpler



and not in a good way. An assistant professor of cell biology

and paediatrics at Suny Downs Medical Center in Brooklyn, New York she recalls long strategy sessions with her senior graduate student on coaxing their ancient, huge cell sorter to perform. But since purchasing a compact, highly automated Bio-Rad S3 cell sorter in January 2014, her team zips through its sorts and can move on to thinking about their research

"It is really a piece of equipment for small labs who want to ask questions and don't want the sorting to take on a life of its own," she says. "The sorting is just a means to get you a tool to do the experiment '

The S3 also makes it easier for Blain, who co-directs a small core facility for her department to train users and eave them to work unsupervised while she teaches classes or does her own research.

Instruments for fluorescence activated cell sorting were once uniformly bulky and required experts at core facilities to operate. But a new generation of smaller, cheaper sorters that have emerged in the past few vears allows researchers to perform simple sorts on their own, often with only brief training.

The larger sorters are faster and can handle more colours, "but we didn't need to sort with 10 colours", says Blain. "We could get what we wanted with four colours," and the smaller machines are still relatively fast, she said.

KATE Y MANDELL/THE SCIENTIST

loning foreign DNA in bacterial genes will contain only gene-coding C cells is now a routine procedure. In practice, obtaining a good source of DNA to serve as starting sequences, without the non-coding interruptions called *introns* that are common in eukaryotic genes. Introns material is often one of the most difcan be so extensive that the overall length of a eukaryotic gene becomes

TAPAN KUMAR MAITRA EXPLAINS WHY

ficult steps. Two different approaches are commonly used for obtaining DNA starting material. In the "shot gun" approach, an organism's entire genome (or some substantial portion thereof) is cleaved into a large number of restriction fragments, which are then inserted into cloning vectors for introduction into bacterial cells (or phage particles). The resulting group of clones is called a *genomic library* because it contains cloned fragments representing most, if not

FOR DNA CLONING

all, of the genome. Genomic libraries of eukaryotic DNA are valuable resources from which specific genes can be isolated. provided a sufficiently sensitive iden tification technique is available Once a rare bacterial colony that con tains the desired DNA fragment has been identified, it can be grown on a nutrient medium to generate as many copies of the fragment as may be needed. Of course, the DNA cuts made by a restriction enzyme do not respect gene boundaries and some genes may be divided among two or more restriction fragments. This problem can be circumvented by car rying out a partial DNA digestion in which a small quantity of restriction enzyme is used for a brief period of

restriction sites remain uncut increasing the probability that at least one intact copy of each gene will be present in the genomic library

The alternative DNA source for cloning experiments is DNA that has been generated by copying messenger RNA (mRNA) with the enzyme reverse transcriptase. This reaction generates a population of *comple*mentary DNA (cDNA) molecules that are complementary in sequence to the mRNA employed as template. If the entire mRNA population of

a cell is isolated and copied into cDNA for cloning, the resulting group of clones is called a cDNA *library*, the advantage of which is that it contains only those DNA sequences that are transcribed into mRNA — presumably, the active genes in the cells or tissue from which the mRNA was prepared.

In addition to being limited to transcribed genes, a cDNA library has another important advantage as a sta-rting point for the cloning of eukaryotic genes. Using mRNA to make cDNA guarantees that the cloned

manipulation. Using cDNA elimi-nates this problem. In addition, bac BOTH GENOMIC AND CDNA LIBRARIES ARE USEFUL teria cannot synthesise the correct protein product of an intron-containing eukaryotic gene unless the introns have been removed — as they are in cDNA

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too unwieldy for recombinant DNA

interference pattern.



appropriate cloning vector

Preparation of complementary DNA (cDNA) for cloning: 1) Messenger RNA is incubated with reverse transcripise, which uses the mRNA as a template for synthesis of a complementary DNA (cDNA) strand. Oligo(dT), a short chain of thymine deoxynucleotides, can be used as a primer, because eukaryotic mRNA always has a stretch of adenine nucleotides at its 3' end. 2) The resulting mRNA-CDNA hybrid is treated with alkali or an enzyme to hydrolyse the RNA, leaving the single-stranded cDNA a) DNA polymerase can now synthesise the complementary DNA strand. The looped-around 3' end of the first DNA strand can often be used as a primer. An enzyme called S1 nuclease is then used to leave the loop. 4) For efficient insertion in a cloning vector, the double-stranded DNA must have single-stranded tails that are complementary those of the vector. These can be added by incubation with terminal transferase, an enzyme that adds nucleotides one at a time to the ends of incubation with terminal transferase, an enzyme that adds nucleotides one at a time to the ends o the molecule. If short, stretches of cytosine (C) nucleotides, for example, are added to the cDNA and short stretches of guanine (G) nucleotides are added in the same way to a linearised cloning vector, recombinant molecules can be generated by allowing the single-stranded C tails in the cDNA to hybridize to the single-stranded G tails in the vector. (As an alternative to step 4, short synthetic "linker" molecules containing a variety of restriction sites can be ligated to the ends of both the cDNA and a blunt-ended cloning vector. The linkers are then cleaved with a restriction enzyme that generates sticky ends.)

technology and is the earliest bronze object to have been found in Britain,

that his social position may well have depended on his demonstrating his prowess in combat. The blade of the dagger with its rivet-studded handle res

earchers said. of bronze-working techniques, when metalsmiths in Britain learnt from the Continent how to mix their cop

## nent member of society, someone of great seniority," said Dr Stuart Nee-dham, a Bronze Age specialist who also worked on the project, adding



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