Before your children are born, their children could turn up at your door.

Michael Brooks discovers how to turn the future into the past.

RONALD MALLETT thinks he has found a practical way to make a time machine. Mallett isn't mad. None of the known laws of physics forbids time travel, and in theory, shunting matter back and forth through time shouldn't be that difficult.

The catch usually comes when you try to make it work in practice. Remember wormholes, those clever little tunnels in space and time that can supposedly be used to travel from one moment to another? On paper, they're a perfectly respectable way to travel back in time. Trouble is, you need a supply of exotic "negative energy" matter to prise your wormhole open.

But Mallett, a professor of theoretical physics at Connecticut University, believes he has found a route to the past that uses something much more down to earth: light. Mallett has worked out that a circulating beam of light, slowed to a snail's pace, just might be the vital ingredient for time travel. Not only is the technology within our grasp, Mallett has teamed up with other scientists at Connecticut to work towards building it. "With this device," he says, "time travel may become a practical possibility."

It may be hard for us to climb into Mallett's time machine, as slowing light down requires temperatures close to absolute zero. But future, advanced civilisations might work out a way to do it. And they might even come back to tell us how. If it works in the way Mallett believes it might, his device would provide time travellers from the future with their first gateway into our history.

Mallett began his journey into the past when he was just ten years old. In 1955, his father died of a heart attack. "For me, the sun rose and set on him. It completely devastated me," Mallett says. But then he came across *The Time Machine* by H. G. Wells. Even as a child, Mallett knew his father hadn't taken care of himself. Drinking and heavy smoking took a toll on his weak heart, and it gave out at the age of 33. "My notion was that if I could build a time machine, I might be able to warn him about what was going to happen," Mallett says. "That became my guiding light."

What started as a childish notion grew into a passionate investigation of everything ever written about time travel. When Mallett studied the work of Einstein--who died in the same year as his father--he realised that Wells's novel was right on track: time travel is, in theory at least, achievable.

Einstein himself found the notion upsetting, but he had only himself to blame. He showed that the effect we call gravity is a bending of space and time. Anything that has mass or energy distorts the space and the passage of time in its vicinity, a bit like the way the surface of a soft couch is distorted when someone sits on it. Solving Einstein's gravitational field equations tells you just how space-time is distorted by mass and energy.

A lump of matter stretches space and time. So, for example, clocks run slower in the gravitational field close to Earth than they do far out in space. And if you set a massive lump spinning, it begins to whip space and time around after it, like a rotating teaspoon dragging the foam on a cup of coffee. The denser and faster-moving the matter, the more strongly it distorts space-time.

Take this idea far enough, and you find that time can be twisted so much that instead of running in an infinite line from past to future, it is bent into a ring. Follow this loop around, and you return to a particular moment, just as a walk around the block brings you back to your front door.

Theoreticians have found some solutions to Einstein's equations that include these "closed time-like loops"--physicists' jargon for a time machine. The first to do so was the Austrian-born mathematician Kurt Gödel, in 1949, but unfortunately his solution required the whole Universe to be rotating--which it's not. Decades later Kip Thorne of Caltech came up with the idea of using wormholes, which link different regions of warped space-time, to provide such loops. Other loops can be made by infinitely long, spinning cylinders--somewhat hard to come by--or fast-moving cosmic strings. In the early Universe, these ultra-dense strands of matter may have been as common as dirt, but alas, no longer.

Mallett's idea of using light is much less outlandish. "People forget that light, even though it has no mass, causes space to bend," he says. Light that has been reflected or refracted to follow a circular path has particularly strange effects. Last year, Mallett published a paper describing how a circulating beam of laser light would create a vortex in space within its circle (Physics Letters A, vol 269, p 214). Then he had a eureka moment. "I realised that time, as well as space, might be twisted by circulating light beams," Mallett says.

To twist time into a loop, Mallett worked out that he would have to add a second light beam, circulating in the opposite direction. Then if you increase the intensity of the light enough, space and time swap roles: inside the circulating light beam, time runs round and round, while what to an outsider looks like time becomes like an ordinary dimension of space. A person walking along in the right direction could actually be walking backwards in time--as measured outside the circle. So after walking for a while, you could leave the circle and meet yourself before you have entered it (see Diagram, opposite).

The energy needed to twist time into a loop is enormous, however. Perhaps this wouldn't be a practical time machine after all? But when Mallett took another look at his solutions, he saw that the effect of circulating light depends on its velocity: the slower the light, the stronger the distortion in space-time. Though it seems counter-intuitive, light gains inertia as it is slowed down. "Increasing its inertia increases its energy, and this increases the effect," Mallett says.

As luck would have it, slowing light down has just become a practical possibility. Lene Hau of Harvard University has slowed light from the usual 300,000 kilometres per second to just a few metres per second--and even to a standstill (**New Scientist**, 27 January, p 4). "Prior to this, I wouldn't have thought time travel this way was a practical possibility," Mallett says. "But the slow light opens up a domain we just haven't had before."

To slow light down, Hau uses an ultra-cold bath of atoms known as a Bose-Einstein condensate. "All you need is to have the light circulate in one of these media," Mallett says. "It's a technological problem. I'm not saying it's easy, but we're not talking about exotic technology here; we're not talking about creating wormholes in space."

Mallett has already caught the interest of his head of department, William Stwalley, who leads a group of cold-atom researchers. Their first experiment will be designed only to observe the twisting of space, by looking for its effect on the spin of a particle trapped in the light circle. If they can then add a second beam, Mallett believes evidence of time travel will eventually appear.

He's not sure how time travel would manifest itself. Perhaps what starts out as a single trapped particle would acquire a partner--the particle visiting itself from the future.

Stwalley is more interested in the practical challenges of the experiment, and remains sceptical about possibilities of time travel. "A time machine certainly seems like a distant improbability at best," he says.

Last month, Mallett gave his first talk on the idea at the University of Michigan at the invitation of astrophysicist Fred Adams, who accepts that the theoretical side of Mallett's work stands up to scrutiny. "The reception was cautious and sceptical," Adams admits. "But there were no holes punched in it, either. The solution is probably valid."

But even Adams isn't convinced that the experiment will work. That's hardly surprising, as time travel raises disturbing questions. Could you go back and murder your grandparents, making your birth impossible? There may be ways out of this problem (see "Paradox lost"), but most physicists think that any attempt to mess with history should be impossible. The Cambridge astrophysicist Stephen Hawking calls this the "chronology protection conjecture".

The general theory of relativity, which Mallett used to work out his theory of time travel, does not take account of quantum mechanics. Could this be the crucial omission that means time machines won't work in the real Universe? Hawking and Thorne say that any time machine would magnify quantum fluctuations in the electromagnetic field, and destroy itself with a beam of intense radiation. But to know for sure, we need a theory of quantum gravity--a theory that merges quantum theory with relativity.

Even Mallett doesn't claim that time travel is definitely within reach. "Whether it will do what I predict is something that one will only know by performing the actual experiment," he says. Then there's the problem of getting on and off the loop of time without destroying it--or yourself. "I really don't know whether you could use this in the sense of H. G. Wells's time machine," says Mallett.

But who knows? In a few years, we may have entered an era when time travel is possible, and all kinds of strange people, things and situations from the future might come to visit. One thing seems certain, though. Even if the Connecticut time machine works, it won't be taking any Yankees back to the court of King Arthur. Mallett's circle of light won't allow anyone to travel back beyond the point where time first formed a closed loop. So it will be impossible to go back to a time before it was set up. "A later person could only travel back to the time when the machine is turned on," Mallett says. This may explain why we have never been overrun by visitors from the future.

It also means that although Mallett might change the Universe, he won't ever achieve his childhood dream. Mallet's father will remain forever beyond his reach.

From **New Scientist magazine**, 19 May 2001.

Paradox lost

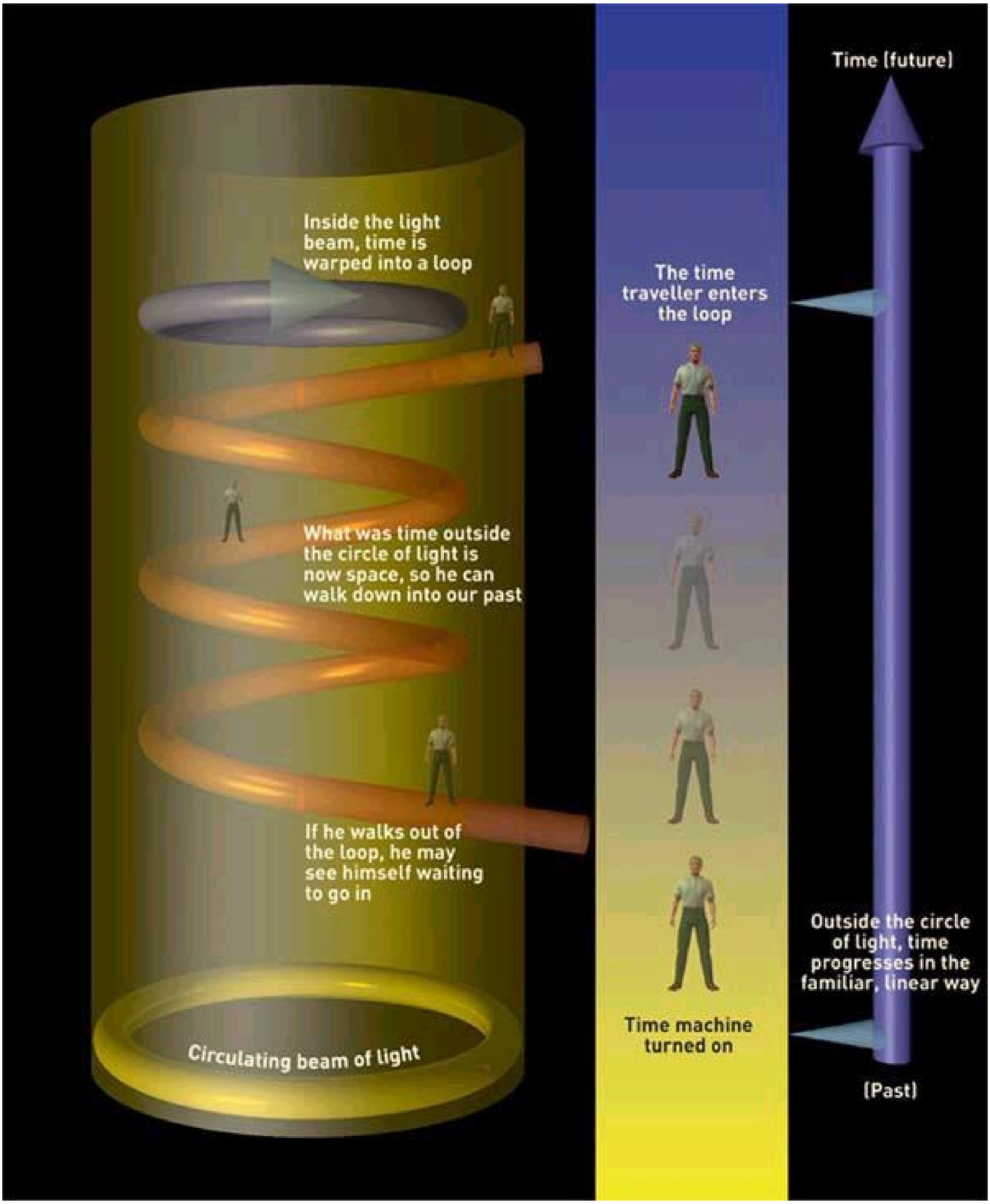
Time travel is littered with paradoxes. The most notorious is the idea of travelling back to the time before your parents were born and killing your grandparents, making it impossible that you would ever exist. And if you didn't exist, you wouldn't be able to travel back, so you wouldn't kill your grandparents, so you would be born after all . . . Any influence on the past can lead to self-contradictory logical loops like this.

People have dreamed up ways to try to break out of the loop. One is the "consistent histories" approach, which says that you must be somehow forbidden from doing anything that would change the past. However hard you try, something will stop your killing spree. But this is uncomfortably deterministic. In a universe with time travel, should everything be predetermined?

Another way out is the "alternative histories" hypothesis. In this idea, you go back to a different history from the one you left. You are free to do anything in this alternate version of history--killing your grandparents included. It won't change anything in the history where you originated.

This has parallels in the "many worlds" interpretation of quantum mechanics, an explanation of how the bizarre quantum laws allow unobserved particles such as atoms and electrons to be in two places at once. Every time an observation forces them to choose one position or another, a new universe is created--one where they took one position, one where they took the other. So perhaps a time machine would take you into a parallel universe

From **New Scientist magazine**, 19 May 2001.



From **New Scientist magazine**, 19 May 2001.