An extensive study at a US Buddhist retreat suggests the ancient eastern practice of meditation might delay the ageing process by protecting our chromosomes from degenerating. Jo Marchant reports

High in the mountains of northern Colorado, a 100-foot tall tower reaches up through the pinetops. Brightly coloured and strung with garlands, its ornate gold leaf glints in the sun. With a shape that symbolises a giant seated Buddha, this lofty stupa is intended to inspire those on the path to enlightenment.

Visitors here to the Shambhala Mountain Centre meditate in silence for up to 10 hours every day, emulating the lifestyle that monks have chosen for centuries in mountain refuges from India to Japan. But is it doing them any good? For two three-month retreats held in 2007, this haven for the eastern spiritual tradition opened its doors to western science. As attendees pondered the "four immeasurables" of love, compassion, joy and equanimity, a laboratory squeezed into the basement bristled with scientific equipment from brain and heart monitors to video cameras and centrifuges. The aim: to find out exactly what happens to people who meditate.

After several years of number-crunching, data from the so-called Shamatha project is finally starting to be published. So far the research has shown some not hugely surprising psychological and cognitive changes – improvements in perception and wellbeing, for example. But one result in particular has potentially stunning implications: that by protecting caps called telomeres on the ends of our chromosomes, meditation might help to delay the process of ageing.

It's the kind of claim more often associated with pseudoscience. Indeed, since researchers first started studying meditation, with its close links to religion and spirituality, they have

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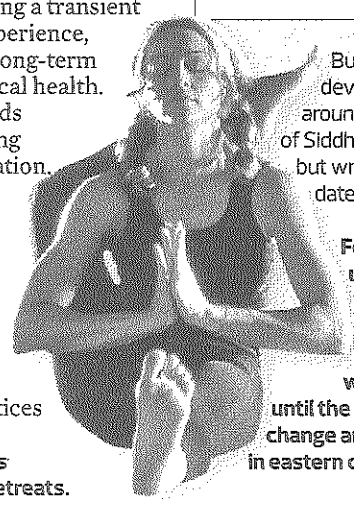
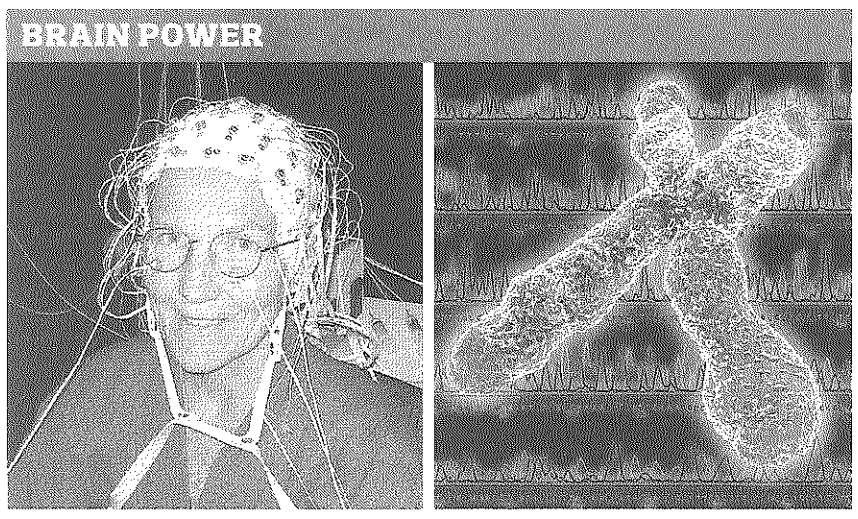
had a tough time gaining scientific credibility. "A great danger in the field is that many researchers are also meditators, with a feeling about how powerful and useful these practices are," says Charles Raison, who studies mind-body interactions at Emory University in Atlanta. "There has been a tendency for people to be attempting to prove what they already know."

But a new generation of brain-imaging studies and robust clinical trials is helping to change that. Scientists from a range of fields are starting to compile evidence that rather than simply being a transient mental or spiritual experience, meditation may have long-term implications for physical health.

There are many kinds of meditation, including transcendental meditation, in which you focus on a repetitive mantra, and compassion meditation, which involves extending feelings of love and kindness to fellow living beings. One of the most studied practices



Like a prayer: Madonna is known to attend silent retreats.



Left: a Shamatha project meditator is fitted with a cap that measures brain waves. Right: computer artwork of an X chromosome – the red regions mark out telomeres.

is based on the Buddhist concept of mindfulness, or being aware of your own thoughts and surroundings. Buddhists believe it alleviates suffering by making you less caught up in everyday stresses – helping you to appreciate the present instead of continually worrying about the past or planning for the future.

"You pay attention to your own breath," explains Sara Lazar, a neuroscientist who studies the effects of meditation at Massachusetts general hospital in Boston. "If your mind wanders, you don't get discouraged, you notice the thought and think, 'OK'."

Small trials have suggested that such meditation creates more than spiritual calm. Reported physical effects include lowering blood pressure, helping psoriasis to heal, and boosting the immune response in vaccine recipients and cancer patients. In a pilot study in 2008, Willem Kuyken, head of the Mood Disorders Centre at Exeter University, showed that mindfulness meditation was more effective than drug treatment in preventing relapse in patients with recurrent depression. And in 2009, David Creswell of Carnegie Mellon University in Pittsburgh found that it slowed disease progression in patients with HIV.

Most of these trials have involved short courses of meditation aimed at treating specific conditions. The Shamatha project, by contrast, is an attempt to see what a longer, more intensive course of meditation might do for healthy people. The project was co-ordinated by neuroscientist Clifford Saron of the Centre for Mind and Brain at the University of California, Davis. His team advertised in Buddhist publications for people willing to spend three months in an intensive meditation retreat, and chose 60 participants. Half of them attended in the spring of 2007, while the other half acted as a control group before heading off for their own retreat in the autumn.

It sounds simple enough, but the project has taken eight years to organise and is likely to end up costing around $4m (partly funded by private organisations with an interest in meditation, including the Fetzer Institute and the Hershey Family Foundation). As well as shipping laptops all over the world to carry out cognitive tests on the volunteers before the study started, Saron's team built a hi-tech lab in a dorm room beneath the Shambhala centre's main hall, enabling them to subject participants and controls to tests at the beginning, middle and end of each retreat, and worked with "a village" of consulting scientists who each wanted to study different aspects of the meditators' performance. "It's a heroic effort," says neuroscientist Giuseppe Pagnoni, who studies meditation at the University of Modena and Reggio Emilia in Italy.

Many of the tests focused on changes in cognitive ability or regulation of emotions. Soft white caps trailing wires and electrodes measured the meditators' brain waves as they completed gruelling computerised tasks to test their powers of attention, and video recordings captured split-second changes in facial expressions as they watched images of suffering and war.

But psychologist Elissa Epel, from the University of California, San Francisco (UCSF), wanted to know what the retreat was doing to the participants' chromosomes, in particular their telomeres. Telomeres play a key role in the ageing of cells, acting like a clock that limits their lifespan. Every time a cell divides, its telomeres get shorter, unless an enzyme called telomerase builds them back up. When telomeres get too short, a cell can no longer replicate, and ultimately dies.

It's not just an abstract concept. People with shorter telomeres are at greater risk of heart disease, diabetes, obesity, depression and degenerative diseases such as osteoarthritis and osteoporosis. And they die younger.

Epel has been collaborating with UCSF's Elizabeth Blackburn, who shared the 2009 Nobel physiology or medicine prize for her work on telomeres, to investigate whether telomeres are affected by psychological factors. They found that at the end of the retreat, meditators had significantly higher telomerase activity than the control group, suggesting that their telomeres were better protected. The researchers are cautious, but say that in theory this might slow or even reverse cellular ageing. "If the increase in telomerase is sustained long enough," says Epel, "it's logical to infer that this group would develop more stable and possibly longer telomeres over time."

Pagnoni has previously used brain imaging to show that meditation may protect against the cognitive decline that occurs as we age. But the Shamatha project is the first to suggest that meditation plays a role in cellular ageing. If that link is confirmed, he says, "that would be groundbreaking".

So how could focusing on your thoughts have such impressive physical effects? The assumption that meditation simply induces a state of relaxation is "dead wrong", says Raison. Brain-imaging studies suggest that it triggers active processes within the brain, and can cause physical changes to the structure of regions involved in learning, memory, emotion regulation and cognitive processing.

The question of how the immaterial mind affects the material body remains a thorny philosophical problem, but on a practical level, "our understanding of the brain-body dialogue has made jaw-dropping advances in the last decade or two," says Raison. One of the most dramatic links between the mind and health is the physiological pathways that have evolved to respond to stress, and these can explain much about how meditation works.

When the brain detects a threat in our environment, it sends signals to spur the body into action. One example is the "fight or flight" response of the nervous system. When you sense danger, your heart beats faster, you breathe more rapidly, and your pupils dilate. Digestion slows, and fat and glucose are released into the bloodstream to fuel your next move. Another stress response pathway triggers a branch of the immune system known as the inflammatory response.

These responses might help us to run from a mammoth or fight off infection, but they also damage body tissues. In the past, the trade-off for short bursts of stress would have been worthwhile. But in the modern world, these ancient pathways are continually triggered by long-term threats for which they aren't any use, such as debt, work pressures or low social status. "Psychological stress activates these pathways in exactly the same way that infection does," says Raison.

Such chronic stress has devastating effects, putting us at greater risk of a host of diseases including diabetes, cancer, heart disease, depression – and death. It also affects our telomeres. Epel, Blackburn and their colleagues found in 2004 that stressed mothers caring for a chronically ill child had shorter telomeres than mothers with healthy children. Their stress had accelerated the ageing process.

Meditation seems to be effective in changing the way that we respond to external events. After short courses of mindfulness meditation, people produce less of the stress hormone cortisol, and mount a smaller inflammatory response to stress. One study linked meditators' lower stress to changes in the amygdala – a brain area involved in fear and the response to threat.

Some researchers think this is the whole story, because the diseases countered most by meditation are those in which stress plays a major role. But Epel believes that meditation might also trigger "pathways of restoration and enhancement", perhaps boosting the parasympathetic nervous system, which works in opposition to the fight or flight response, or triggering the production of growth hormone.

In terms of the psychological mechanisms involved, Raison thinks that meditation allows people to experience the world as less threatening. "You reinterpret the world as less dangerous, so you don't get as much of a stress reaction," he says. Compassion meditation, for example, may help us to view the world in a more socially connected way. Mindfulness might help people to distance themselves from negative or stressful thoughts.

The Shamatha project used a mix of mindfulness and compassion meditation. The researchers concluded that the meditation affected telomerase by changing the participants'

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psychological state, which they assessed using questionnaires. Three factors in particular predicted higher telomerase activity at the end of the retreat: increased sense of control (over circumstances or daily life); increased sense of purpose in life; and lower neuroticism (being tense, moody and anxious). The more these improved, the greater the effect on the meditators' telomerase.

For those of us who don't have time for retreats, Epel suggests "mini-meditations" – focusing on breathing or being aware of our surroundings – at regular points throughout the day. And though meditation seems to be a particularly effective route to reducing stress and protecting telomeres, it's not the only one. "Lots of people have no interest in meditation, and that's fine," says Creswell. Exercise has been shown to buffer the effects of stress on telomeres, for example, while stress management programmes and writing emotional diaries can help to delay the progression of HIV.

Indeed, Clifford Saron argues that the psychological changes caused by the Shamatha retreat – increased sense of control and purpose in life – are more important than the meditation itself. Simply doing something we love, whether meditating or gardening, may protect us from stress and maybe even help us to live longer. "The news from this paper is the profound impact of having the opportunity to live your life in a way that you find meaningful."

For a scientific conclusion it sounds scarily spiritual. But researchers warn that in our modern, work-obsessed society we are increasingly living on autopilot, reacting blindly to tweets and emails instead of taking the time to think about what really matters. If we don't give our minds a break from that treadmill, the physical effects can be scarily real.

INNER JOURNEYS A history of meditation

Buddhists in India began to develop meditation as a practice around 500BC, under the tutelage of Siddhartha Gautama, the Buddha, but written records of meditation date back as far as 1500BC.

Forms of meditation were used in ancient Greece, among early Christians and in Judaism, but the practice did not become widespread in the west until the 1960s, driven by social change and a surge of interest in eastern culture.

A government survey in 2007 found that more than 20 million US adults, or 9.4% of the population, had practised meditation within the past 12 months.

Famous meditators include David Lynch, Nick Clegg and William Hague, who have practised transcendental meditation; Madonna, who goes on silent retreats; and Meg Ryan, who practises mindfulness.

More than 1,000 scientific studies of meditation in the English language have been documented.