COMMENT

S. MAXWELL/ASPEN CENTER FOR PHYSICS

Summer workshops at the Aspen Center for Physics give researchers respite from their academic duties.

Aspen physics turns 50

Michael S. Turner reflects on how mountain serenity has bred big breakthroughs at the Aspen Center for Physics in Colorado.

Theoretical physicists are an odd lot: bad communicators (Niels Bohr and Werner Heisenberg); brilliant showmen (Richard Feynman and George Gamow); the 'strangest man' (Paul Dirac), lots of Hungarians (Leó Szilárd, Edward Teller and Eugene Wigner); bad hair (Albert Einstein); and too few women. They don't need fancy equipment — a pencil and paper will do. But they do like a serene environment, with blackboards and others of their ilk, in which to come up with big ideas: among them relativity, the Big Bang, quantum mechanics and the atomic bomb.

Over the past 50 years, the Aspen Center for Physics (ACP), nestled in a beautiful valley at 2,400 metres in the Colorado Rocky Mountains, has provided a 'circle of serenity' during the summer months for 10,000 theoretical physicists, including 53 Nobel laureates, from 65 countries. The centre can lay claim to the string theory revolution, the birth of the arXiv preprint archive and to setting the agenda in condensed matter physics. Its history is tied to the revival of a silver mining town and the American entrepreneurial spirit, and includes a fascinating cast of characters, from philosopher Mortimer Adler to journalist Hunter S. Thompson.

The centre's story cannot be separated from that of the town. The 1893 repeal of the Sherman Silver Purchase Act demonetized silver and almost overnight turned Aspen, with a population of about 15,000, into a ghost town. Elizabeth Paepcke, wife of Chicago industrialist Walter Paepcke, visited in 1939, describing it as a place that "had slept since 1893". She found 700 residents, decaying Victorian buildings and wonderful skiing. She persuaded her husband, a devotee of German writer Johann Wolfgang von Goethe, to visit in 1945. Seeing it as the ideal place to bring together the three elements of life — economic, cultural and physical — he invested millions of dollars in rebuilding it. In 1946, he formed the Aspen Skiing Corporation, which remains the financial engine of the valley.

Aspen's cultural transformation came with the 1949 Goethe bicentennial. Organized by Walter Paepcke (with guidance from Adler and Robert Maynard Hutchins, then president of the University of Chicago), the bicentennial aimed to rehabilitate German culture and to revive humanism in the wake of the Second World War and the dawn of the atomic age. Around 2,000 people gathered in a tent designed by architect Eero ▶

Saarinen for the 20-day celebration. They included German–French theologian Albert Schweitzer, pianist Artur Rubinstein, philosopher Jose Ortega y Gasset and poet Stephen Spender. The event led to the formation of the Aspen Music Festival (now the Aspen Music Festival and School) and, in 1950, of the Aspen Institute for Humanistic Studies (now the Aspen Institute). Just as Paepcke had imagined, today the town brings together culture, wealth and athleticism — with a touch of glitz.

BEGINNINGS

The ACP's origins lie with physicist George Stranahan, heir to the fortunes of the Champion Spark Plug company and a graduate student at the Carnegie Institute of Technology in Pittsburgh. In the late 1950s, he decided that he would rather do his physics during the summer months in the mountains of Colorado, where fishing and hiking provided a more enjoyable backdrop than an office in steamy Pittsburgh. After a few years, he realized that theoretical physics is best done with others, and set out to draw physicists to Aspen. When he later moved to Colorado, Stranahan became the landlord and close friend of Thompson.

Stranahan got things going with help from Michael Cohen, a condensed-matter theorist at the University of Pennsylvania in Philadelphia, who was one of Feynman's few PhD students, and Robert Craig, executive director of the Aspen Institute. The Stranahan family's Needmor Fund paid for the first building, Stranahan Hall, designed by Bauhaus architect Herbert Bayer, who also planned the Aspen Institute campus. Cohen got the physics talent, and Craig convinced the Aspen Institute to create a physics division.

In spring 1962, a letter was sent out to the physics community tentatively announcing "the possibility of a summer physics institute". The purpose was "to provide a place for physicists to work on their own problems during the summer, in a stimulating physics atmosphere, and in a location with pleasant surroundings and natural beauty". That year, 42 brave souls came to Aspen to "pursue their work with minimal distractions".

The Aspen formula was — and still is — to bring the best theorists together in an informal setting for weeks or months, free from their usual responsibilities of students and teaching and isolated from distractions. There, they could talk with one another, think big thoughts and come up with game-changing ideas. Physicists were housed two to an office and held discussions on a patio with a small blackboard, often accompanied by beautiful music from the town's music tent. Graduate students were excluded, differentiating Aspen from teaching summer schools. For many years, the buildings had only a handful of public phones. This put a limit on interruptions, but sometimes provided entertainment. I once overheard particle physicist Murray Gell-Mann quipping, "I don't know the English for it, but the Japanese is …"

An early attempt to engage physicists and philosophers failed because of Adler's insistence that they first agree on "the pyramid of knowledge", which had physics at the bottom and philosophy on top. Because of the clash of cultures and egos, the centre did not stay tied to the Aspen Institute for long and became an independent entity in 1968. Since then, the ACP has been run by physicists who volunteer their time, helped by just two full-time staff. More than 200 top theorists have shaped and guided the centre — including five Nobel laureates and Stephen Hawking.

An early grant from the Sloan Foundation was crucial, and Hans Bethe donated part of his 1967 Nobel prize money. Bethe Hall, built in 1978, was named in his honour. Robert Rathbun Wilson, the first director and builder of Fermilab, visited Aspen in 1967 and convinced the US Department of Energy to build a large, temporary office building there, where Fermilab's facilities for particle-physics experiments were designed. Hilbert Hall, named after mathematician David Hilbert, almost tripled the number of physicists that the centre could accommodate.

SOLID FOUNDATIONS

In 1972, the US National Science Foundation became the ACP's main funder, with support from other US science agencies including the Department of Energy and NASA. In the mid-1990s, a $3-million fund-raising campaign led by astrophysicist David Schramm of the University of Chicago financed the final and largest building, Smart Hall. Contributions came from physicists, friends in the Aspen community and the Smart Family Foundation in Connecticut.

Three towering figures played a major part in establishing the ACP in the theoretical community: Philip Anderson, Bethe and Gell-Mann. Coincidentally, each began coming to Aspen two years before he received a Nobel prize. They set the agenda, served as scientific magnets and gave early legitimacy. Any high-energy theorist would kill to spend three weeks discussing physics with Gell-Mann; Bethe helped to get astrophysics going at the ACP; and Anderson shaped condensed-matter physics there for three decades.

George Stranahan, Michael Cohen and Robert Craig (left to right): the centre's driving forces.

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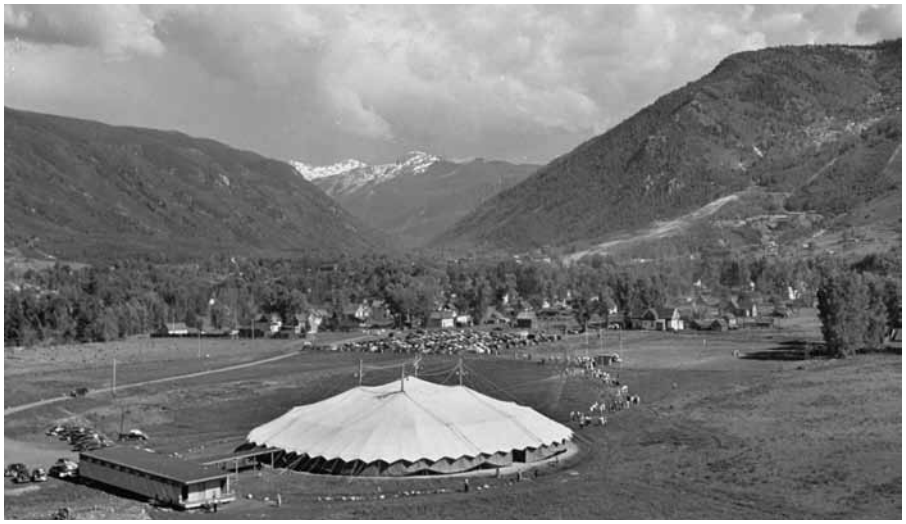
Anderson set the tone for the condensed-matter field with his influential paper 'More is Different' (P. W. Anderson *Science* **177,** 393–396; 1972). Contrary to particle physics, in which scientists pursue a reductionist quest for simplicity at smaller and smaller scales, condensed-matter physics applies the basic rules to discover and study the often unexpected, emergent phenomena that arise in large systems with complicated interactions, such as superconductivity or in biological systems. Today, biological physics has emerged as a major activity at the ACP.

Two other condensed-matter theorists played a crucial part: David Pines of the University of Illinois at Urbana–Champaign and Elihu Abrahams of Rutgers University in New Jersey. They pioneered workshops on the latest topics to attract a balance of researchers from universities and from industry (mostly Bell Labs). These workshops brought in young hotshots, keeping the talent pool fresh. One area of scientific focus, strongly correlated electrons in metals, laid the foundations for the current understanding of high-temperature and other unconventional superconductors.

In addition to Bethe's presence, astrophysics at the ACP was jump-started by the discovery of pulsars in 1967 and their identification with neutron stars. The exotic properties of neutron stars — rapid rotation, superfluidity and superconductivity — intrigued Pines and other condensed-matter theorists. They brought in astrophysicists with expertise in relativity and nuclear physics, and work done at the centre linked pulsar glitches to superfluidity within neutron stars, advancing both fields. In 1972, NASA started funding an annual workshop, and astrophysics had a foothold in Aspen.

But it was cosmology that caused astrophysics to rise to the same level as particle physics and condensed matter. Around 1980, Schramm and others began to realize that theories of unification in particle physics might revolutionize the sleepy field of cosmology, which had been the province of astronomers since the time of Edwin Hubble. Aspen was the ideal incubator for this young, interdisciplinary field. Workshops brought together astronomers and physicists to discuss the hot topics — Big Bang nucleosynthesis, dark matter, inflation, large-scale structure, the cosmic



W. EUGENE SMITH/TIME & LIFE PICTURES/GETTY

Aspen's cultural shift started with big-top celebrations for Johann von Goethe's bicentennial in 1949.

microwave background and cosmic strings.

A staggering 10,000 or more papers are attributed to visits to the ACP. But its real impact is the big ideas that originated there. Much of today's consensus cosmology, with its particle dark matter, inflationary origins and dark energy, can trace its roots to the ACP. In his Nobel prize acceptance speech last December, Adam Riess described how his team, which co-discovered that the expansion of the Universe is speeding up, regularly met at the centre to chart their activities.

STRINGING IT TOGETHER

Whether or not string theory is the theory of everything, it has changed the course of physics. String theory began as a way to describe the strong interactions between neutrons, protons and related particles. Supersymmetry, the symmetry between bosons and fermions and a hallmark of today's string theory, traces its origins to theorist Pierre Ramond's first summer in Aspen in 1970, where, as he put it, he "stopped calculating and started thinking". When he got back to Fermilab, he prepared the paper that added supersymmetry to string theory. This has become the pattern: think in Aspen, calculate and write at home.

String theory was declared dead at a 1974 Aspen workshop, having been beaten by quantum chromodynamics as the best description of the strong (colour) interactions between the quark constituents of the hadrons. But John Schwarz of the California Institute of Technology decided to be bold and think bigger, touting strings as the path to unifying the forces of the subatomic world with gravity. For the next ten years, Schwarz, his collaborator Michael Green and a handful of others tried to make good on this promise at the centre. In the summer of 1984, their breakthrough came with a historic paper that showed the mathematical consistency of string theory (technically the cancellation of anomalies), triggering the first string theory revolution.

The Green–Schwarz discovery was announced immediately in grand fashion during a 'physics cabaret' at Aspen's historic Hotel Jerome. In a skit in which Schwarz played the role of Gell-Mann, he rushed onto the stage to announce that he had discovered the theory of everything — eventually being carried off the stage by a man in a white coat.

Another revolution, in physics publishing, traces its origin to a chance encounter on an ACP bench in June 1991. Joanne Cohn, a young theorist at the Institute for Advanced Study in Princeton, had been running an informal preprint distribution service, e-mailing papers to hundreds of string theorists who wanted to get the latest results as quickly as possible. Paul Ginsparg, then at Los Alamos, asked her why she hadn't automated the system. By the next day, Ginsparg had written some scripts, and two months later the Los Alamos arXiv (now residing at Cornell University) was open for business. Today, more than 1 million articles are downloaded every week (P. Ginsparg *Nature* **476,** 145–147; 2011).

Physicists have always been attracted to mountains, where they can hike and think. ACP co-founder Robert Craig was a world-class mountaineer who scaled some of the toughest and tallest mountains, including K2, and many physicists who came to Aspen were serious climbers. A topographical map of the surrounding mountains is displayed prominently in Stranahan Hall. Aspen's combination of challenging hikes, unpredictable mountain weather and crumbling rock means that tragedies are not uncommon.

In 1988, ACP trustee Heinz Pagels, executive director of the New York Academy of Sciences, slipped on a loose stone while climbing on Pyramid Peak and fell to his death. A respected popularizer of physics as well as a brilliant theoretical physicist, Pagels' name was given to the centre's summer public lecture series.

Schramm, my mentor, was an expert climber. One summer, bad weather trapped him and his climbing partner on the face of Capitol Peak in freezing rain; they made it back to Aspen two days later, after many had given up hope. Sadly, in December 1997, Schramm was less fortunate, and died in a plane crash while flying his twin-engine turboprop from Denver to Aspen.

THE FUTURE

Today, the Aspen Center for Physics is thriving, made up of three buildings on a 1.6-hectare campus, surrounded by a large 'circle of serenity' of open space on the Aspen Meadows. Along with the Aspen Institute and the Aspen Music Festival and School, the ACP is recognized as one of the town's three major cultural institutions.

Each summer, its 16-week programme and 10–15 workshops attract more than 500 leading theorists to work on the most critical problems in physics. With delight, I note that about 20% of the attendees and members of the governing board are now women, and the centre now has its first female president — progress for theoretical physics. Discussions fill the offices, halls, alcoves and patios; spontaneous volleyball games occur regularly. New ideas and collaborations made in this informal environment have launched the careers of hundreds of young theorists (myself included) and moved physics forwards.

Will the Aspen formula continue to be as successful as it has been for the past 50 years? Several theoretical-physics institutes now exist — the Isaac Newton Institute in Cambridge, UK, and the Kavli Institutes in Santa Barbara and Beijing. These have longer, more formal programmes, and lack the serenity of Aspen. The bigger challenge comes with the change in the way science is done today. It is more collaborative, more connected and 'more faster'. When the ACP was founded, collaboration required face-to-face interaction. Now, with e-mail and the Internet, many successful collaborators have never met in person.

Aspen continues to be a place to think, free from the constraints of everyday existence — as Paepcke said, a place for "lifting us out of our usual lives". In today's fast- paced world of science, the need for a circle of serenity is only more acute. ■

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For more on 50th anniversary events at the Aspen Center for Physics, see go.nature.com/lepwz8.