ed by DNA damage (Fig. 1c) and, like p66
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Figure 2 Cellular response to oxidative stress and DNA damage. In wild-type mouse cells, both agents induce apoptosis. In mutants that lack both copies of the P66SH gene, oxidative damage does not induce cell death but DNA damage does. In mutants lacking both copies of the p53 gene, neither agent induces cell death.

that calorie restriction helps people to live longer. Preliminary findings indicate that the physiological changes associated with calorie restriction in rodents also occur in primates11. We may be at a watershed in the study of ageing. A more robust response to oxidative damage is associated with longer life in mutants of the nematode worm C. elegans and the fruit fly D. melanogaster. Migliaccio and colleagues are the first to show that a simple genetic modification of this response can increase lifespan in a mammal. In humans, drugs given later in life might circumvent any costs in development or reproduction. We should therefore look forward to a growing research area nurtured by, if not the fountain of youth, more than a trickle of hope.

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news and views

Molten rocks in motion

Michael R. Perfit

We only see the Earth’s mantle in action when it melts and rises to the surface, most spectacularly during a volcanic eruption. The 70,000-km-long, global network of mid-ocean ridges is the site of the most abundant and steady supply of magma (and after cooling, new crust) on Earth. Detailed investigations during the past two decades have greatly expanded our view of volcanic and tectonic processes at ocean ridges, but we still have a limited understanding of how magma is delivered to, and concentrated in, the relatively narrow zones of volcanic and hydrothermal activity along spreading ridges.

On page 282 of this issue, Spiegelman and Reynolds1 attempt for the first time to distinguish between different dynamic models of mantle melting beneath ocean ridges by comparing them with geochemical data9 from basalts (volcanic rock) that erupted in the northern section of the fast-spreading East Pacific Rise. There is not yet a consensus on the style of mantle melting, but Spiegelman and Reynolds have taken a first step towards trying to reconcile theory with observation.

Chemically, samples of mid-ocean ridge basalts from the oceanic crust have provided indirect information about the composition of the mantle and the chemical and physical processes that can modify magma, but have so far given little insight into the dynamics of melting or upwelling of mantle material14,15. How and where the mantle melts, how magma interacts with the solid mantle matrix on its way to the sea floor, how the chemistry of basaltic magma varies in space and time and how the upper oceanic crust is formed, are all questions that have yet to be answered.

Two fundamentally different theories have been proposed to explain the volcanic activity associated with spreading ridges6,7. One model assumes that magma flow is dynamic or ‘active’ (it buoyantly rises and helps drive plates apart) and the other assumes that magma rises passively (it rises in response to the plates being pulled apart). In the first case, magma is concentrated in a narrow zone directly below the ridge axis, whereas in the other magma converges from a wide area below the ridge towards this narrow zone (Fig. 1, offshore). In both models magma is concentrated beneath the ridge crest, but tests to determine which model is correct have been wanting.

Geophysical studies8 and results from the recent MELT experiment9 — the most comprehensive seismic and electromagnetic study across the southern East Pacific Rise 10 have shed new light on our view of the upper mantle where basalts form. Both methods used can detect the presence of magma
because seismic velocities change when they pass through molten rocks and electrical conductivity is much higher in magma than in solid rocks. In the MELT area, seismic data suggest that small amounts of magma (<2%) are asymmetrically distributed around the ridge axis, in a region extending much farther to the west (up to 350 km) than to the east, and to depths possibly as great as 130 km. The electromagnetic evidence is consistent with this finding but also suggests that magma may be present to even greater depths and that the amount of magma is much lower in the east than the west. These results support models for passive magma flow, because the magma appears to converge on the ridge axis from such a wide area in the mantle. But is this consistent with what volcanic and geochemical studies have found along other segments of the East Pacific Rise?

Recent seafloor studies and radioactive dating of basalts on the East Pacific Rise indicate that volcanic eruptions occur both ‘on-axis’—that is, within a narrow zone along the ridge summit—as well as ‘off-axis’ in the crestal plateau, in a region up to ~5 km away (Fig. 2). Some of the basalts found off-axis are geochemically distinct from ‘normal’ basalts recovered closer to the ridge axis. In an upcoming paper, Reynolds and Langmuir  show that off-axis basalts in the 12°N region of the East Pacific Rise are more depleted in certain elements such as Na, P, Ti and Zr, compared with basalts recovered from the ridge axis. Given what we know (or think we know) about melting and magma flow below ridges, it is difficult to explain such a spatial variation in composition.

We may now have an answer. The melt models discussed by Spiegelman and Reynolds  show that off- and on-axis magmas will differ in composition depending on whether the flow is passive or active in the mantle. The geochemical characteristics of basalts from 12°N are consistent with passive flow, whereby small amounts of magma formed over a wide region in the mantle converge on the volcanic zone. These findings are significant because they are consistent with results from the MELT experiment. They suggest that basalt chemistry can be used as an independent tool to study processes associated with ridge dynamics that are difficult to test with geophysical techniques and geodynamic models alone.

But some problems remain. First, it is not easy to say with certainty which basalts actually erupted off-axis, and which erupted at the ridge axis and were subsequently transported to an off-axis location by spreading. Second, the 12°N area is one of the few areas of the East Pacific Rise where enriched basalts are located on-axis and depleted types are found off-axis. The opposite is true in other parts of the northern East Pacific Rise (12°N). How do these areas fit into the picture? Can different segments only a few hundred kilometres apart have different mantle melting styles? Is the distribution of basalts types perhaps related to ocean spreading cycles (for example, active ridges versus those that are starved of magma)? Finally, geophysical data such as those obtained during the MELT experiment do not exist for the northern East Pacific Rise, so it is unclear if those results apply here.

Spiegelman and Reynolds’ attempt to pin down a conceptual model for mantle melting is but a first step towards a more complete understanding of melting processes in the upper mantle and their role in creating ocean crust. Despite some widely spaced sampling of basalts along the East Pacific Rise, few areas of the global mid-ocean ridge system have been sampled in detail. So how applicable this model is to other ocean ridges, or even to other fast-spreading segments of the East Pacific Rise, remains to be tested. Correlating the composition of surface basalts and their distribution on the sea floor with models of magma generation in the mantle is a challenge that must be met by marine geologists, geophysicists and geochemists in the coming decades. Fine-scale mapping and sampling of more tectonically diverse segments of the global ridge system will allow us to form a better picture of the mantle processes that ultimately determine the volcanic and tectonic activity that creates the oceanic crust.

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Molecular motors

What makes ATP synthase spin?

Paul D. Boyer

Many years ago, when enzymes were first recognized as being proteins, few people could have imagined the wondrous, precise and diverse structures that make possible their catalytic and other functions. The ATP synthase enzyme, for example, performs catalysis as a molecular mechanism. On page 263 of this issue, Rastogi and Girvin report the latest insights into this mechanism. Using sophisticated NMR and chemical probes, they have revealed structural changes in a critical subunit that could drive the rotation.

ATP synthase, also known as F, FATPase, catalyses the formation of ATP (adenosine triphosphate) from ADP (adenosine diphosphate) and P (inorganic phosphate), in processes known as oxidative phosphorylation (driven by oxidations in animal cells and microorganisms) and photophosphorylation (driven by light in plant cells). Once formed, ATP is cleaved back to ADP and P by the enzyme — it provides the energy to drive a myriad of metabolic processes including biosyntheses, muscle contraction, and nerve and brain function.

A model of the enzyme (Fig. 1) shows a hydrophilic F, portion above the F, part, which is embedded in a phospholipid bilayer membrane. The F, portion from various sources is made up of three a subunits, three b subunits and one each of the e, and $\gamma$ subunits. The three catalytic sites are found mainly on the b subunits. In the F, portion from the bacterium Escherichia coli, there are one a subunit, two b subunits and 9–12 c subunits. The F, portion from various plants and animals is more complex, but it still contains the multiple copies of c-type subunits.

As demonstrated by Peter Mitchell, energy from oxidation–reduction reactions is captured by the formation of an electrochemical gradient of protons across the membrane. This advance — and the growing knowledge about proteins and the ATP synthase enzyme — provided the basis for a suggestion that I made a quarter of a century ago. The idea was that the protonation and deprotonation of a carboxyl group in F, as protons cross the membrane, results in protein conformational changes coupled to the formation of ATP. Rastogi and Girvin now clothe this concept with reality.

Since this proposal, much has been learned about the ATP synthase. The three catalytic sites are known to pass sequentially through three different conformations associated with substrate binding, formation of tightly bound ATP, and release of the ATP. These changes are thought to occur through a rotational catalysis in which, as indicated in Fig. 2 (overleaf), rotation of the e subunit causes the requisite sequential changes in the $\beta$ subunits. The concept of a binding-change mechanism with rotational catalysis received strong support five years ago when John Walker’s group reported the X-ray structure of the major portion of F, This structure was consistent with the idea that three different conformations of the $\beta$ subunits are interconverted by rotation of the $\gamma$ subunit. Avail-

Figure 1 Model of the Escherichia coli ATP synthase. The enzyme consists of two parts known as the F, and F, portions. The F, portion comprises three a subunits, three b subunits, an $\epsilon$, $\delta$ and $\gamma$ subunit. The F, portion contains one a subunit, one $\beta$ subunit and 9–12 c subunits. (Courtesy of R. L. Cross, State Univ. New York, Syracuse.)

100 YEARS AGO

The authors of this research on the behaviour of rifle barrels were induced to make an experimental investigation of the behaviour of rifle barrels, in order to clear up certain difficulties connected with that which is known in ballistics as the error of departure. It had been noticed that in shooting with a rifle (whether loosely, or firmly fixed), that the initial tangent to the trajectory — “die Anfangstangente der Flugbahn” — does not coincide, as would be expected, with the axis of the bore of the barrel, when produced, but is more or less inclined to it at a small angle; this is called the angle of error of departure.

The collection of photo-chronographic records, twenty-eight in number, show the manner in which a rifle barrel vibrates when subjected to the concussion due to an explosive. The authors show that the experimental results agree well with figures calculated on the assumption that the rifle barrel is a cylindrical tube.

From Nature 16 November 1899.

50 YEARS AGO

‘Data’

Nature of September 3 contained a letter under this heading. In it Prof. A. V. Hill asks that the word be used in its original sense, that is, as the plural of datum, for which he gives the “Oxford English Dictionary” definition “A thing given or granted” and so on. He adds that there may sometimes be an excuse for regarding data as a collective singular in the same way as agenda. In my view, the word ‘data’ has now come to be generally accepted as having a wider meaning than one based on its Latin derivation. It is used, still as the plural of datum, to indicate a collection of facts or, more often, figures, and these may, indeed, be regarded as ‘things given’ to the reader for the argument or discussion based on them. Changes in the meaning of a word are common in a language that is still alive and should, I suggest, be welcomed as a sign of life. On the other hand, not even Prof. Hill will convince me that one may deliberately change the grammar of a word. ‘Data’ was a plural noun; for literate English writers it still is, and I contend that it always should be.

From Nature 19 November 1949.