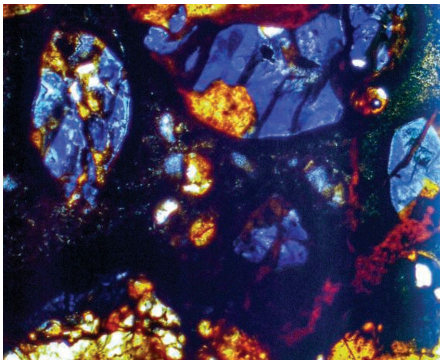

**Deep-mantle minerals in a meteorite.** This shock-melt vein in the L chondrite, Roosevelt County 106, consists of quenched chondritic melt (nearly black matrix) with entrained meteorite fragments. The olivine in the fragments has transformed into deep-blue ringwoodite. The image is about 1 mm wide.

of very high pressures and locally high temperatures that melt and transform meteoritic materials into the same high-pressure phases that make up the deep Earth. During shock, the impacted rocks are compressed to pressures of more than 25 GPa. In highly deformed regions, such as sheer bands or collapsed pores, sample temperatures exceed the melting temperatures of the materials (~2500 K at 25 GPa), resulting in shock-melt veins and pockets (*9*). It is in and adjacent to these melt zones that olivine, pyroxene, and plagioclase get hot enough to transform into their high-density polymorphs.

Shocked meteorites have provided natural examples of deep-mantle minerals (see the second figure) since Binns *et al.* (*10*) discovered ringwoodite, the spinel-structured polymorph of olivine, in a shocked chondrite and named it after A. E. Ringwood. Many high-pressure minerals have been named after important high-pressure experimentalists. Bridgmanite is thus a very fitting name for the most abundant mineral in the Earth. Continued investigation of shock effects in meteorites and terrestrial rocks will likely provide many more natural examples of minerals from deep within Earth or other planetary bodies. ■

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PSYCHOLOGY

# How quickly we forget

## Why do we recall some things better than others?

*By* **David C. Rubin**

Since the beginning of the scientific study of human memory, there has been a tension between those who stress experimental control, even at the risk of oversimplifying and thus losing aspects of the behavior of interest (*1*), and those who stress studying behavior as close as possible to the way it exists naturally, with only enough control to produce replicable results (*2*, *3*). The first approach optimistically assumes that the theory tested in the laboratory will generalize to more varied situations; the second counters that a careful, preferably quantitative, description of the phenomenon is needed—close to its full complexity—before a reasonable theory can be formulated, otherwise important aspects may be removed before a theory is considered. When it is possible, as in the study by Roediger and DeSoto (*4*) on page 1106 of this issue, combining both approaches is the most productive strategy.

Roediger and DeSoto examined the pattern and rate at which individuals (in the United States) forget U.S. presidents over time. The authors examined two groups—three generations of students (totaling 415 individuals in 1974, 1991, and 2009) from different U.S. universities, and 497 adults in 2014. Among their observations is a similar pattern of enhanced recall of the first U.S. presidents (Washington, Adams, and Jefferson), of Lincoln, of the current president (at the time of testing), and of presidents close in time to the time of the test (attributed to the "recency effect"). On the basis of their results, Roediger and DeSoto extrapolate when the fame of recent presidents, as measured by the ability of people to recall them, will reach the level of Presidents Fillmore, Buchanan, and McKinley (who were not well remembered).

The findings of the study overall suggest an integration of personal memory and the memory of major historical events. This is because of an observed continuity in memory for historical events (U.S. presidents) that occurred before and after one's birth. The recall data of Roediger and DeSoto decrease smoothly with time from the pres-

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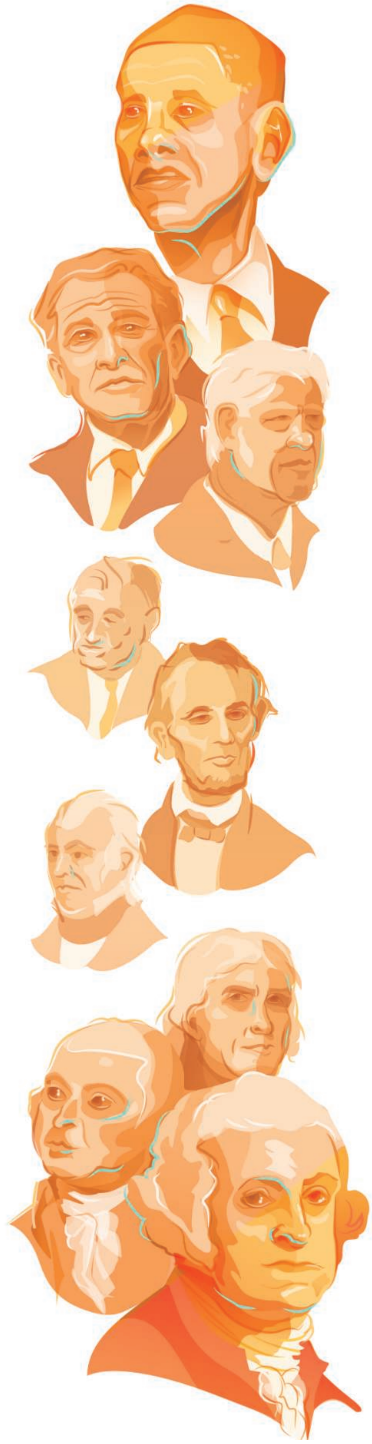
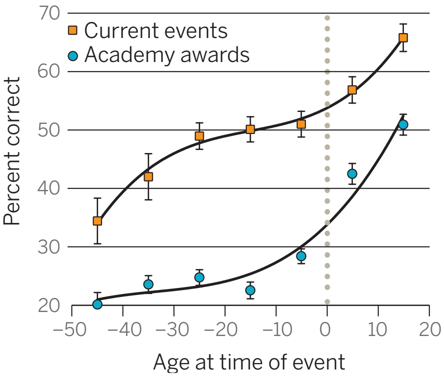


**Remember the president?** Across generations (since the 1970s), people in the United States forget U.S. presidents in the same way, with strongest recall only for the earliest and most recent presidents (but also for Lincoln) (*4*).

PHOTO: THOMAS SHARP; ILLUSTRATION: V. ALTOUNIAN/*SCIENCE*

## Knowledge of events




**Awards and events.** Correct answers to multiple-choice questions are shown as a function of participants' age at the time of the event. The vertical dotted line denotes the birth of the participants. The *y* axis begins at the chance guessing level of 20%. [Adapted from (*5*).]

ent that does not change dramatically at birth or during early development, a time period from which adults can recall few memories. For a variety of topics, including current events, entertainment, and sports, the difference between one's life and historical time is not a major factor (*5*). Two examples are winners of Academy Awards and important news events (see the graph). Acquisition of such historical knowledge is from exposure that need not come at the time of the event and in which the number and spacing of repeated exposures and the mechanisms of human cognition can make some events memorable beyond their historical importance (*5–8*).

There are two explanations for the smooth decrease in recall from the present observed by Roediger and DeSoto that are based on when and how often a person is reminded of an event, not on other factors. At a systems level, the probability that particular knowledge will be needed can be estimated from its recent past usage, with remote usage having a smaller effect. This past usage can be used to adjust its availability for recall—much as a library might arrange books for ease of access by recent popularity—but also considering, to a lesser degree, remote usage (*9*). In addition, based on past usage, the number and recency of past exposures could be all that affects ease of recall. Thus, if one has repeatedly heard about something in the past few months, it is more likely to be recalled.

However, beyond the impact of the environment, there is considerable knowledge of memory mechanisms from studies of information learned and retained over the life span and over generations, which can be used to understand why some things are recalled better than others. A key factor is the nature of the longer-term spacing of "rehearsal." For instance, Bahrick and Hall (*8*) found minimal loss in knowledge of high school algebra over 50 years among people who took at least one college course at or above calculus level, whereas those who did equally well in high school algebra but took no college mathematics declined to near-chance levels of remembering algebra. Similarly, Bahrick (*7*) found that individuals who took Spanish courses in high school or during college (spaced over multiple semesters) but were not exposed to Spanish thereafter lost much of that knowledge within the first 6 years after their final Spanish class. This observed recall as a function of time is similar to that observed by Roediger and DeSoto. Similarly, annual holidays (such as Veterans Day in the United States) and more widely spaced commemorations (such as might occur at 10-, 25-, or 100-year intervals after the end of a war) provide this spaced rehearsal for historical events.

With respect to cognitive mechanisms, memories of historical events, people, and even monuments meant to serve as reminders are all affected more by visual and spatial imagery than by other factors such as narrative (*6*). The combination of cues from various sensory modalities, emotion, language, narrative, and especially visual and spatial imagery of scenes helps keep memory available and stable for centuries, well above what would be expected from the mnemonic effects of individual cognitive systems used in isolation (*10–12*).

By combining careful measurement techniques with the study of events that span centuries, Roediger and DeSoto demonstrate the potential for the scientific study of the transmission and retention of cultural knowledge based both on exposure and the mechanisms that shape human memory. ■

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CELL BIOLOGY

# *Powering the cell cycle*

## Cell division is linked to mitochondrial protein transport

*By* **Christian Schulz**[1] *and* **Peter Rehling**[1,2]

To live means to grow, respond, reproduce, and adapt. All these processes require energy, which in most eukaryotic cells is provided by mitochondrial oxidative phosphorylation. Moreover, mitochondria have been implicated in other vital cellular processes, including programmed cell death (apoptosis) and calcium signaling. Hence, mitochondrial functions have to be tightly integrated into the cellular context, and the mechanisms that participate in this coordination are only just beginning to be understood. On page 1109 of this issue, Harbauer *et al.* (*1*) identify a link between the cell division cycle and mitochondrial protein transport as a driver of this process.

To maintain mitochondrial functionality and thus ensure cellular survival, newly synthesized mitochondrial proteins must be imported into the organelle from the cytoplasm. Numerous pathways supply the various mitochondrial subcompartments with their resident proteins. How these transport processes are integrated into the cellular context and adapted to the cellular requirements is only recently becoming apparent (*2*, *3*). An unexpected observation is that mitochondrial protein translocation is regulated by cytosolic and mitochondrial enzymes (protein kinases). A major phosphorylation target of these kinases is the translocase of the outer membrane (TOM), which represents the entry gate for almost all protein precursors destined for the mitochondria.

Tom6 is a constituent of the TOM complex, and its expression (at the transcription level) undergoes a cell cycle–dependent regulation (see the figure) (*4*). Thus, Harbauer *et al.* investigated the fate of the Tom6 protein during the cell cycle in budding yeast. A marked increase of Tom6 during the $G_2$ phase–M phase transition in the cell cycle led to the identification of a cyclin-dependent kinase 1 (Cdk1)– and cyclin Clb3–mediated phosphorylation event on serine-16 of cytosolic Tom6 protein. This modification increased the rate of import of Tom6

**How quickly we forget**
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Editor's Summary