Remember the Future

by Susan M. Fitzpatrick

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Editors: Henry L. Roediger, Yadin Dudai, Susan M. Fitzpatrick

If the *conceptual* focus of this book is not reason enough for readers to treat it as a rarity among collected writings on memory, the inclusion of this chapter might offer another. I doubt that many collections of scientific papers focusing on memory and the products of memory research include a contribution from someone who has never engaged in the study of memory. What can a foundation officer and biochemist, whose research interests (when she was actively engaged in laboratory research) were studies of metabolism in the cerebral cortex add to this collection of essays?

The reasons I initially chose to study metabolic pathways, my later career switch to philanthropy, and my involvement in the *Science of Memory: Concepts* are related, even if not immediately obvious. From my very first introduction to scientific research, I was drawn to the study of metabolism—the interaction of enzymes, substrates and effectors most nonbiochemists only see depicted as the complicated 'roadmap' diagrams hanging on the walls of biology classrooms. I found metabolic pathways, particularly those associated with the production of cellular energy, beautiful. I also had this feeling that it was the right place to be if you wanted to understand how the brain works.

What do I mean, '. . . it felt like the right place to be?' Today, I would mean that the level of analysis occupied by intermediary energy metabolism, the processes that provide the energy needed to fuel the work of the brain, is a necessary span to have in place if we hope to bridge from genes to molecules, to systems, to behavior. Although I did not know it 20 years ago, seeking 'the right place to be' when trying to answer a question would come to define the nature of the work that I do as a foundation officer and the way I think about science.

Thinking about 'the right place to be' is also responsible for initially sparking the conversations that ultimately resulted in the McDonnell Foundation's involvement in the Science of Memory project. I was responsible for developing and teaching a general neuroscience course for students pursuing graduate degrees in the Washington University's School of Occupational Therapy. Designing this course raised several questions for me:What do Occupational Therapists need to know about how the nervous system supports behavior? What is the right level of detail? How do I connect what is presented in the standard neuroscience texts with their concerns about people living real lives in the real world? How do I cover the required information, at the right depth, in 28 class-days? For some topics, there seemed to be an easily identified 'right place to be'. However, when it came to outlining the two class days devoted to 'memory', I was truly befuddled. Considering the enormous role memory plays in everyday life and the number

of ways memory function can be altered by environmental factors, including disease, injury and aging, I agonized over how I was to get it right. The neuroscience text we were using, along with the classic text of neuroscience this course used as a reference, presented a somewhat odd subset (at least to my way of thinking) of what we know about memory—what I have come to call the '*Aplysia*/monkey delayed nonmatch to sample/H.M.' science of memory. Understandably, in two lectures, one can only cover so much, and this selection might not, in some ways, represent a bad choice.What bothered me, however, was that the texts gave the impression that what we knew about habituation in the *Aplysia* flowed seamlessly up to (and offered an explanation for) what we knew about the abilities and disabilities of the famous H.M. The texts, from my reading, suggested that all the richness of the human experience we ascribe to 'memory' could be explained by events occurring at and identified by the molecular level. Of course one can find a richer story in psychology texts, but this was a neuroscience class with the goal of understanding the neurological underpinnings of behavior. Pondering whether my discomfort was primarily due to my naiveté with the full scope of memory research, I did what I usually do when I am not quite certain that my take on a topic is sure-footed. I checked with the experts. Luckily for me, one of the experts willing to listen to my concerns was Endel Tulving. Endel took the nub of what was certainly a naïve discomfort and helped guide it in a direction more interesting and profound. What followed then was a series of conversations beginning with philosopher of science Carl Craver and gradually involving a widening circle of very serious memory scholars willing carefully to consider the question Carl and I posed as a deceptively simple one: Do we have an integrated science of memory? More importantly, the early discussions, culminated in Endel Tulving, Yadin Dudai and Roddy Roediger agreeing to work with the McDonnell Foundation on developing an approach for answering the posed question. A plan emerged to bring together a working group to discuss how concepts of fundamental importance to memory are employed (or not) across various memory research traditions, from the cellular to systems to behavior. (For a discussion on the process for selecting the 16 concepts presented in this volume see Chapter 1.) Our hope was that such an evaluation would identify those places where there are meaningful gaps in our knowledge and would generate interesting new research questions. Such was the rationale behind this volume. From my perspective, some degree of success on both outcomes has been achieved in the essays collected here.

By engaging in the conversations that took place during the project and reading the resulting essays collected in this volume, I see several interesting 'gaps' that could generate new memory research questions. One challenge will be deciding at what levels meaningful biological explanations for the psychology of behavior are likely to be found. (For other discussions along this line, see Chapters 16 and 17).

From my own research perspective, it is worth considering how we can use studies of energy metabolism to further the science of memory. Metabolism occupies a level somewhere in the middle ground between the molecular and the functional. Damage to oxidative metabolic pathways or to the mitochondria (the 'powerhouses of the cell') keeps cropping up as targets in neurological studies of conditions characterized by declining cognitive function. (Mattson and Magnus 2006) However, in my experience,

psychological studies of memory rarely consider the constraints of energy demands. Even cognitive neuroscientists employing functional imaging tools that rely on biomarkers such as blood flow changes or rates of oxidative metabolism to study neural correlates of mental function are rarely interested in how the actual energetic demands enhance or constrain the performance of such tasks. In the essays in this volume specifically dealing with evolution, there is little discussion of the metabolic costs that might be associated with the different kinds of memories and/or how energetic considerations may constrain the selection processes by which memory systems evolved. Energy, as we know from our visits to gasoline stations, is expensive. Successful organisms do not waste it.

The science of memory, as represented in this volume, is also missing, along what might be considered a 'biochemical line', a serious discussion of the role of the various neurotransmitter systems. Except for some discussion of inhibitory neural transmission (see Chapter 49), the roles of neurotransmitters is usually mentioned in passing. (There is some mention of neurotransmitters in the essays in Chapters 7, 8, 10 and 36.) From the perspective of a biochemist, items on any future agenda for the science of memory should include integrating energetic demands and limitations and the role of neurotransmitter systems into what we know about the processes and systems that support memory behavior and their evolution. One question could be: have energetic considerations and neurotransmitter functions contributed to the strengths and fallibilities of memory, particularly human memory? Another is: how do we best study such questions?

When I peer out from under the brim of my foundation hat, I see that the science of memory could be enhanced by reaching out to ideas from the science of complex systems. A complex systems approach would mean explicitly studying how different levels of organization within neural, cognitive, and behavioral systems interact (Simon 1974; see also Gunderson and Holling 2001). Too often, the difficulties of interlevel analysis are brushed off with rhetorical handwaving.

While I offer energetic and pharmacological considerations as needed additions to a science of memory—and while my own bias leads me to believe such efforts could enrich the science of memory—I am not suggesting that they are necessarily 'the right place to be'. Since the business of individual neurons is to alter their characteristics in response to experience, it is likely that at lower levels of analysis what we think of as distinct aspects of memory (implicit, explicit, semantic, procedural, and so on) will look fairly similar. (For an alternative view, see Chapters 9 and 58.) This does not mean memory research at molecular levels is unnecessary. However, it does mean that if we want to link cellular and molecular events to behavior, we can only do so by careful study at the intervening levels of analysis, including the neural networks and brain systems at which memory representation is most likely to be coded (see Chapter 11).

A second challenge will be linking the findings from experimental psychology's studies of memory to memory in everyday life—or what might be best described as the 'ordinary bloke's science of memory.' The task for researchers is to decipher how experimental results obtained from laboratory experiments map onto everyday memory (or more broadly, the behaviors supported by memory working in concert with other

experimentally isolatable cognitive systems) and what are by-products of the artificial conditions of experimental design (see Chapter 46).

A third area where an investment in effort will yield a wealth of returns is a better understanding and characterization of the uniqueness of human memory (see Chapters 43, 64 and 65). 'Gaps' such as these can only be filled via a broad comparative examination of memory processes in a variety of species and careful evaluation of the similarities and differences. This observation brings me back to energy metabolism. Because the energetic demands of running the human brain are very expensive, there must be a good reason why natural selection settled on costly solutions. Otherwise we could all make do with a tiny, energetically cheap brain and be happy.How does human memory serve uniquely human behaviors?

I have no doubt that those interested in memory will uncover a treasure trove of possible research questions by carefully reading the essays in this volume. Additional questions will surely be revealed by an effort to read between the lines. Even more emerge from what is not covered in the volume at all. Much of what is discussed between the covers of this book focuses almost exclusively on memory research using individual subjects (except perhaps in the essay including bee behavior, Chapter 63). How do we bridge from what is revealed about individual memory to rich traditions of scholarship studying why we create books, visual images, monuments and museums? In what ways do these external repositories of memory mirror the fragilities and/or the robustness of our individual memory systems? How might they make recompense for the sometimes ephemeral nature of our remembrances? A whole field of the humanities (especially in English and history) is concerned with 'memory studies' in which scholars ask questions about memory in very different traditions. In many parts of the world (the Middle East, the Balkans, India and Pakistan), ethnic groups are fighting today because of collective memories of events that happened hundreds or even thousands of years ago. A form of memory spurs these conflicts, even though no one alive today experienced the events that cause such anger and grief in today's world (Wertsch 2002).Will these uses of collective memory ever be linked to and understood through analyses of very different researchers as represented in this volume?

I hope that in 25 years someone initiates a new dialogue on where we are in building an integrated science of memory. I hope those conversations lead to a new Science of Memory project and result in an entirely new and different volume of essays. I hope I am still around. I would very much like to read that book.