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BRAIN PLASTICITY AND SPANISH MOSS IN BIOLEGAL ANALYSIS

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Between the emotion
And the response
Falls the shadow.

-T.S. Eliot, "The Hollow Men"

I. INTRODUCTION

The University of Florida and its law review should be commended for choosing Owen Jones for this year's Dunwody Lecture. Professor Jones is still a young man, and as he acknowledges, he is by no means the first to write about the important connections between law and biology. Nevertheless, he should properly be regarded as a founding father of law and biology in the same way that Judge Richard Posner is often regarded as a founding father of law and economics. Both are enormously energetic and productive in their efforts to bring together two disciplines. Both have played critical roles in forming organizations where similarly interested individuals can share ideas and challenge one another.[1] Perhaps most

* Professor of Law, Vanderbilt University. Special thanks to Oliver Goodenough, David Gordon, Margaret Gruter, Owen Jones, and Todd Zywicki for helpful comments, support, and encouragement. I am also grateful to the Dean's Fund at Vanderbilt Law School for financial support.

1. Professor Jones is a founder of the Society for Evolutionary Analysis in Law and has

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importantly, both nurture newcomers with an admirable willingness to set aside their own work to assist others, cheerfully and patiently, in their efforts to grasp the tools of another discipline and advance the ball of understanding. The field of law and biology is growing rapidly, and the good scholarship typically has much to do with Owen Jones. His Article in this volume exemplifies the sophisticated and careful nature of his work.

The general message that Professor Jones disseminates in his articles is important.[2] Law cannot reach peak effectiveness unless it is built on a sound behavioral model, and no model of human nature is ultimately sound unless it is consistent with the insights from behavioral biology.[3] And the beauty of behavioral biology, for one who uses behavioral models, is that it tells us something about human tastes, preferences, and cognitive biases and limitations.

For example, economic models assume a utility function for individuals which specifies individual tastes for goods and/or aversion to bads. Individuals' preferences are ranked in some assumed way, and then the model is used to predict how people will react to changes in their environments. How will recycling behaviors change if the city provides blue boxes in which to place the items at the curb? How will they change if instead consumers must pay a refundable deposit when they purchase goods in recyclable containers? What if the city gives a trophy to the citizen who recycles the most in a given year? What if the mayor just makes a speech at a public event asking the residents to bring their items to a recycling center to help cut down on the costs of trash collection? What if the residents' taxes are raised to take account of the costs of not recycling? What if each household is charged on a per bin basis for non-recycled trash collection? What if non-recyclers' addresses are listed in the newspaper each week? And, if each of these alternatives can be predicted to have some positive effect on recycling behavior, which will be most effective at improving the situation, and which can stimulate a given amount of recycling at the cheapest cost?

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served as the group's President since its inception. He also maintains a website for the organization that includes an impressive list of research materials for interested scholars. http://www.sealsite.org/.

2. Margaret Gruter, Executive Director of the Gruter Institute for Law and Behavioral Research, has also based her life's work on promoting the understanding of this message within law. http://www.gruterinstitute.org/.

3. *See, e.g.*, Owen D. Jones, *Sex, Culture and the Biology of Rape: Toward Explanation and Prevention*, 87 CAL. L. REV. 827, 833 (1999) [hereinafter Jones, *The Biology of Rape*]; Owen D. Jones, *On the Nature of Norms: Biology, Morality, and the Disruption of Order*, 98 MICH. L. REV. 2072, 2073-74 (2000) [hereinafter Jones, *On the Nature of Norms*] (reviewing FRANCIS FUKUYAMA, THE GREAT DISRUPTION: HUMAN NATURE AND THE RECONSTITUTION OF SOCIAL ORDER (1999)); Owen D. Jones, *Time-Shifted Rationality and the Law of Law's Leverage: Behavioral Economics Meets Behavioral Biology*, 95 NW. U.L. REV. 1141 (2001) [hereinafter Jones, *Time-Shifted Rationality*].

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We cannot answer these questions very well unless we have a richer understanding of what people care about and how they will respond to different threats and rewards. In economics, if we assume that people will always maximize wealth, without regard to other, nonmonetary "goods" or "bads," we obtain naïve, often counterintuitive results. If instead we assume that people maximize utility, we have begged an essential question: what do people care about, and how do they rank their preferences?[4]

Behavioral biology can help us understand what people will care about and how they will evaluate the tradeoffs. If the "price" of recycling goes down, people may demand more of it. But why? Is it reasonable to assume that people will care about conservation in the first place?[5] Is there anything that we can do to make them care? And, is there any reason to believe that a five-cent deposit will be more or less effective than publishing the names of non-recyclers? In short, economic models become more useful to policymakers if we can get into the black box of the individual utility function and move beyond the assumption that people have whatever tastes work most conveniently for the model.[6] If we can theoretically discern not only whether people will value A and B but also how A will likely be valued relative to B, then the practical value of predictive models will be significantly enhanced. And, as always, margins matter.

II. MARGINS MATTER

With an eye for analytical symmetry, Professor Jones has quickly recognized that law and biology can be improved by more sophisticated models of the effects of biology on behavior. Economics, defined as "the allocation of scarce resources among competing ends,"[7] aids biology as

4. In general, economists have been unwilling to explore individual tastes and preferences. Jack Hirshleifer, *Economics From a Biological Viewpoint*, 20 J.L. & ECON. 1, 17 (1977) ("Modern neoclassical economics has forsworn any attempt to study the source and content of preferences, that is, the goals that motivate men's actions. It has regarded itself as the logic of choice under conditions of 'given tastes.'").

5. Consumers apparently do care about conserving their environments. *See* Peter S. Menell, Symposium, *Environmental Federalism: Structuring a Market-Oriented Federal Eco-Information Policy*, 54 MD. L. REV. 1435, 1435 (1995) (citing a Gallop Poll that found more than 90% of consumers polled look for environmentally safe products and are willing to pay more for them).

6. To my knowledge, the first person to make this observation was Jack Hirschleifer. Hirshleifer, *supra* note 4, at 17-26 (discussing biology's important advances in identifying scientifically analyzable human tastes and preferences).

7. WALTER NICHOLSON, MICROECONOMIC THEORY: BASIC PRINCIPLES AND EXTENSIONS 5 (3d ed. 1985). Nicholson continues:

> This definition stresses two important features of any economy that will concern us throughout this book. First, productive resources are scarce—they do not exist

much as biology furthers economics. And, nowhere is Jones's recognition of this fact more evident than in this Article.[8]

To be sure, Professor Jones has always emphasized the importance of analytic clarity. He consistently reminds us that the nature/nurture dichotomy is a false one.[9] He warns us to beware of the Naturalistic Fallacy,[10] but not to land in the Moralistic Fallacy.[11] Correlation does not equal causation,[12] and causal influences by themselves do not imply that behavior is deterministic.[13] It is difficult to steer clear of these errors, but Jones nevertheless navigates flawlessly through the topics he addresses.

> in sufficient amounts to satisfy all human wants. This scarcity imposes a variety of constraints both on the choices available to a society and on the opportunities open to its members: No society can produce all the economic goods desired by all its members; no individual can spend more than his or her income; no one can use more than 24 hours in one day. Rather, choices must be made about how resources will be used, and that necessity leads to the second feature of the definition of economics: the concern with discovering how choices are made among competing ends. By examining the activities of consumers, producers, suppliers of resources, governments, and voters and by focusing on interactions among these agents, economists seek to understand how resources are allocated.

Id.; *see also* GARY S. BECKER, ECONOMIC THEORY 1 (1971) ("[E]conomics is the study of the allocation of scarce means to satisfy competing ends. . . . The ends must be competing in order that value judgments or choices of different kinds are involved. When there are no alternatives, there is no problem of choice and, therefore, no economic problem.").

8. Owen D. Jones, *Proprioception, Non-Law and Biolegal History*, 53 FLA. L. REV. 831 (2001).

9. *See, e.g.*, Jones, *The Biology of Rape*, *supra* note 3, at 874-77 (describing nature/nurture and related proximate/ultimate concepts as complementary rather than dichotomous); Jones, *Time-Shifted Rationality*, *supra* note 3 ("[N]ature and nurture are inseparably intertwined, neither making sense without the other. All biological processes, including normal brain development, ultimately depend upon rich environmental inputs. Similarly, all environmental influences can only be perceived, sorted, mentally analyzed and understood through biological—and therefore evolutionary—processes.").

10. Jones, *The Biology of Rape*, *supra* note 3, at 894. The Naturalistic Fallacy assumes that what is necessarily should be.

11. *Id.* at 894-95 ("The Moralistic Fallacy, in mirror image, is committed whenever one assumes that 'is' follows from 'ought,' such that what ought to be is what is.") (citing Charles Crawford, *The Theory of Evolution in the Study of Human Behaviour: An Introduction and Overview*, *in* HANDBOOK OF EVOLUTIONARY PSYCHOLOGY: IDEAS, ISSUES AND APPLICATIONS 9 (Charles Crawford & Dennis L. Krebs eds., 1998) and Charles Crawford, *Genetic, Ethological, and Evolutionary Perspectives on Human Development*, 20 EVOLUTION & HUM. BEHAV. 138, 139 (1999)).

12. *Id.* at 882.

13. *Id.* at 878 ("Evolved predispositions operate probabilistically and are observable in species-typical, environment-sensitive patterns. Because probability is not inevitability, predispositions simply do not guarantee any behavior from any individual. And even high probabilities about patterns likely to emerge from some small subset of a population tell us little reliable about how a single individual is likely to behave."); Jones, *Time-Shifted Rationality*, *supra* note 3.

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More recently, however, he has begun to incorporate the concept of elasticities into his analysis. In an earlier article, Professor Jones introduced the profound yet elegantly simple notion of "the law of law's leverage."[14] As illustrated in Figure 2 of his Article,[15] law is a tool that we use to change human behavior, and its ability to work as a lever to influence that behavior turns on the degree to which that behavior was adaptive for humans in the environment of evolutionary adaptation (EEA). Marital infidelity will be more difficult to influence than will SEC filings, for example. In this Article, Professor Jones works more explicitly with slopes and elasticities, acknowledging that the fulcrum notion is useful but a bit simplistic. In other words, law's leverage on a given behavior, adaptive or not, will also depend upon the external environment and the individual's immediate goals and alternatives. Not fully comfortable with burdening the reader with formal mathematics, however, Professor Jones sticks with his diagrams, asking the reader to envision human behavior in differing shapes and the environmental landscape with variable contours.

Professor Jones also appears to be developing an instinctive, perhaps proprioceptive awareness that any influence on human behavior is likely mediated by a countervailing one, so that extreme or exact predictions about human behavior are typically flawed in some way. From the perspective of the biologist, a blending of these opposing influences is typically more adaptive than the existence of either alone. Take, for example, the human emotional predispositions toward revenge and forgiveness. If one seeks revenge when wronged, one discourages predation by others. On the other hand, if one is predisposed to forgive others, then that person can avoid the costs of vengeful behavior, which can divert valuable resources away from more productive pursuits. Too often, scholars focus on one or the other countervailing influence, forgetting that evolutionary forces would favor some blending of the two behavioral traits. This recognition, that "optimality" typically requires a compromise among competing resources, is the hallmark of a good economist. In their, jargon there is always a tradeoff, making corner solutions rare.

Other potentially countervailing influences exist in evolutionary theory. Natural selection favors behavior that contributes directly to the survival of the individual and close kin (so that the genes can be passed on). But sexual selection favors behavior that attracts a mate, which can often mean signaling an excess of survival resources. One does this by behaving in ways that threaten survival; conspicuous consumption requires throwing away resources, and the peacock's tail makes escape from predators more difficult. Of course, the ideal strategy is to blend the two together, where,

14. Jones, *On the Nature of Norms*, *supra* note 3, at 2100.

15. Jones, *Proprioception, Non-Law and Biolegal History*, *supra* note 8, at 842.

for example, the conspicuous consumption takes a form that actually does contribute to survival, and we may be able to predict that this behavior will generate the greatest evolutionary success.

If we take into account that both natural and sexual selection are at work, that both biological and environmental influences affect behavior, and that both selfish and other-regarding behaviors can be adaptive, it becomes difficult, in many circumstances, to predict precisely with biology how humans will behave. More importantly, it becomes even more difficult to use biology to predict precisely how humans will respond at the margin to legal efforts to channel their behaviors. Yes, the law of law's leverage predicts that the responsiveness of behavior to law will tend to correlate negatively with the adaptiveness of that behavior in the EEA. But even with the law of law's leverage, we have difficulty predicting how behavior A will be affected by legal reform R in society S at time T, which is precisely the problem that the policymaker must attempt to resolve.

We cannot solve this problem until we know more about the other ways in which behavior A is influenced. How does the society respond to behavior A? Does society respond with shunning and ostracism, with spite and revenge, or with back slapping and congratulations? Is behavior A subject to attempts to educate? Are there other legal methods already in place that affect behavior A? With parental education, strong social norms, and alternative or complementary legal tools, very little law maybe needed to change behavior. Alternatively, education, norms and other law already may have changed the behavior of those who were most easily influenced, so that those otherwise uninfluenced are very much unlikely to respond to legal pressures.

The policy maker must decide how much to invest to change behavior along a given margin at a given time. Peaks, valleys, and the shape of behavior begin to matter a lot. Like Xeno's Paradox, improving the behavioral model seems to get us closer to precise decision making but can never quite get us to perfection. This is no criticism of either Professor Jones or law and biology. The problem for the policymaker preceded the advent of law and biology, and Professor Jones correctly argues that an understanding of behavioral biology can improve legal decisions. He states, "the approach . . . can, at best, only describe the macroscopic features of legal systems. . . . This does not trouble me. . . . [I]ncreasing our understanding of the constraints on and patterns of macroscopic superstructures of legal systems is more than sufficient to demonstrate utility of evolutionary analysis in law."[16] Given that legal decisions typically must be made in any event, all improvements help.

The difficulty of using biology to predict the specifics of law prompts Professor Jones to focus instead on non-law, which turns out to be much

16. *Id.* at 871-72.

more important than we myopic lawyers typically recognize. Just as there are so many more potential species and species' attributes than we actually see in the world, there are many more potential laws than have existed anywhere in the world. And there are clear and somewhat predictable patterns regarding the general topics that law addresses, stemming from the fact that what humans care about is in significant part determined by our biology. By focusing on non-law, we are better able to understand law.

Wisdom and integrity underlie Professor Jones's approach: claim only what you can clearly defend. Unfortunately, however, his conservatism can leave the reader wondering, "so what?" As lawyers, we have little concern for the law that will never arise. We care only about the laws that either exist or could conceivably arise. And a macroscopic analysis, while safe, does nothing to inform the all-important margin between law and non-law. Law and biology will have to go further, as Professor Jones acknowledges. But the next steps will be more difficult, and perhaps more questionable. With the hope of stimulating that intellectual journey, I offer two speculations about the behavioral sciences and what they may be able to tell us about law.

First, I turn Professor Jones's claim about bio-legal history on its head. Part III explores whether behavioral biology can help to glean something useful about those existent laws that seem to contradict his predictions. Second, to balance out the quite powerful notion that our brains are a product of our evolution, I introduce brain plasticity in Part IV to suggest that the physical structures of our brains change with the environments that we create for them. The first speculation suggests that Professor Jones's line of inquiry may tell us something about the desirability of particular laws, and the second will, if correct, help the reader develop a more subtle sense of the interaction between environment and evolution. Both of these speculations, I believe, are fully consistent with the work of Professor Jones and are therefore intended to complement his points.

III. PROPRIOCEPTION AND INTEREST GROUPS

Interest group theory, which lies at the intersection of economics and political science, demonstrates that it is possible, even in representative democracies, for laws to serve small subsets of the population at the expense of the majority. Legislatures have a limited ability to pass laws that benefit the public, and they have a limited amount of information about the types of laws that are needed. Consequently, people who have an interest in the enactment of particular laws have some incentive to organize with similarly-inclined individuals to lobby their representatives for change. These groups testify in the legislature, draft statutes, educate legislators, staff members and journalists, raise funds, circulate petitions, organize protests and rallies, contribute to political campaigns, and provide

employment for retired legislators and their staff. Because some groups organize more cheaply and effectively than others, interest group theory predicts that the resulting laws will be skewed toward the more successful groups.[17] Presumably these groups only lobby for the passage of those laws that benefit their members, without regard to whether such laws might be good for the rest of the society.

Two important points limit the negative implications of this cynical view of government. First, many laws do end up furthering the public interest. The typical voter-citizen may not be active in the political process, but an organized interest group can often end up furthering his or her interests as well.[18] Second, not all legislation proposed by powerful interest groups is ultimately enacted. Two well-organized groups' interests may be at odds with one another, giving the legislature an incentive to avoid taking any action on the issue.[19] In addition, legislators typically seek re-election, and political opponents can capitalize on an incumbent's voting record if it includes support for laws that impose heavy costs on the constituents. If government becomes too laden with interest-group deals, the taxpayers revolt.[20]

Public choice scholars debate the significance of these checks, although they all agree there is some room for special interest laws. Because it is often impossible to tell whether any particular legislation serves the public interest or merely furthers some private interest, public choice theory has practical limitations. The sponsors of successful private interest legislation are unlikely to admit publicly that such legislation serves a private interest. Instead, they make some claim about why the law is good for the public. And public interest legislation often works its way through the legislative process only because some private interest was willing to invest the enormous amounts of energy required to ensure its enactment. If both types of legislation further a private interest and claim a public interest,

17. Better ability to organize may be necessary but is not sufficient to obtain favorable laws. More specifically, laws tend to benefit those groups that are able to (1) organize cheaply and effectively, (2) prevent others from entering the group to usurp a share of the benefits, and (3) minimize intra-group competition that threatens to dissipate the proceeds obtained. *See generally* William R. Dougan & James M. Snyder, *Are Rents Fully Dissipated?*, 77 PUB. CHOICE 793 (1993) (discussing conditions under which interest groups can obtain legislative benefits without fully dissipating the potential rents in the lobbying process).

18. In fact, as you read this passage, you are likely free riding off of some group's efforts to enact laws that will make your community a better place to live.

19. *Cf.* Alan Schwartz & Robert E. Scott, *The Political Economy of Private Legislatures*, 143 U. PA. L. REV. 595, 596-97 (1995) (suggesting that presence of opposing interest groups in private lawmaking institutions tends to result in either inaction or promulgation of vague standards that preserves the status quo ante).

20. *See generally* Gary S. Becker, *A Theory of Competition Among Pressure Groups for Political Influence*, 98 Q.J. ECON. 371, 395 (1983) (arguing that increased dead-weight costs encourage taxpayer opposition to regulation).

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categorization ends up turning instead on the evaluating scholar's normative judgment of the law.

Professor Jones's biolegal perspective might give us some proprioceptive purchase on this public choice dilemma. To illustrate, let us return to our recycling example. Some economists have questioned whether recycling efforts are "efficient" because the efforts appear to require significant time and energy and produce only a limited quantity of recycled products.[21] If people have a sufficiently strong taste for recycling, however, the problem disappears for economists, because the benefits from increasing individual utility offset the recycling costs. Simply claiming a taste for recycling is too easy, however. Both the entrepreneur who wishes to open a recycling facility and the city manager who hopes to lower trash collection costs (in order to increase administrative salaries) will assert that the people want recycling. Paper manufacturers and landfill operators, on the other hand, promote their own interests, by claiming that people do not wish to pay for recycling. The political scientist is left to ponder whether the resulting recycling bill is anything more than special interest legislation.

Behavioral biology can help us form an instinctive sense of individual tastes in this area. If my genes are to survive and thrive, then my progeny must have adequate resources. This reasoning might imply that humans are instinctively conservationist. Conservation is costly, however, and might therefore become important only when it begins to appear necessary to the survival of the genes.[22] And, in fact, the more crowded and resource constrained our world has become, the greater the proportion of time that people seem to spend worrying about conservation.

This reasoning can also be used to evaluate the different methods a government might use to promote or discourage activities. For example, the more closely a legal tool comports with our evolved psychologies, the more powerfully it can combat behaviors that also were strongly adaptive in the EEA. In the words of Amy Wax, sometimes "[i]t [t]akes a [g]ene to [b]eat a [g]ene."[23] Recycling is an admittedly poor example to use here, but rape, domestic violence, and divorce are three areas that are already benefiting from the work of Owen Jones and others.

Behavioral biology might ultimately tell us more, however. I submit that amidst the "delicate, crenellated, lace-like filigree"[24] of laws that are not needless, pointless, useless, or toothless, there is Spanish moss. This

21. A discussion about the economics of recycling can be found at the website for the Political Economy Research Center, located at http://www.perc.org/xam1.htm.

22. Matt Ridley makes a similar claim about ecology. MATT RIDLEY, THE ORIGINS OF VIRTUE: HUMAN INSTINCTS AND THE EVOLUTION OF COOPERATION 213-25 (1996).

23. Amy Wax, *Against Nature—On Robert Wright's The Moral Animal*, 63 U. CHI. L. REV. 307, 322 (1996) (book review).

24. Jones, *supra* note 8, at 854.

Spanish moss jumps from branch to branch like an airborne virus. It is vulnerable, no doubt, to removal, but it can and does exist. Spanish moss is used by florists as a natural-looking camouflage for dirt. The legal Spanish moss to which I refer is just as real and is also used as a cover. The Spanish moss is none other than special interest legislation disguised as public interest law.

Professor Jones's suggestion about biolegal history presupposes that laws reflect the fact that our brains have evolved in a manner that limits what we care about and what tools will affect our behavior. Scarcity and its consequent competition together suggest that laws will be used to give some an advantage relative to others. These laws may have neither the purpose nor the effect that their proponents claimed, and they can exist for a long time before they are weeded from the legal landscape.

Special interest legislation, in both its function and form, can be consistent with what behavioral biology tells us about human tastes. In fact, the more the accompanying political rhetoric makes "sense," at least proprioceptive sense, to the citizens, the more likely the law will be enacted. Although the rhetoric, to be effective, makes sense to our evolved brains, we cannot tell whether these laws ultimately serve only the special interests that lobbied for them or whether they end up benefiting the general public as well.

Nevertheless, behavioral biology might be useful to help identify the dirt beneath the Spanish moss. To succeed, behavioral biology must be able to identify those laws that, despite their accompanying rhetoric, are needless, pointless, useless, or toothless. Rather than affecting behavior in some way that will advantage society, these laws serve only to provide an advantage to one group at the expense of another. I think we already instinctively evaluate rules in this manner. Consider, for example, building codes that require that a particular kind of tile or brick be used in construction. Why, we ask ourselves, would anyone care whether the builder used this tile or some other type that is available on the commercial market? If we cannot identify a reason that credibly comports with what we know humans "legitimately" care about, then we begin to wonder whether a particular tile or brick company might have some special influence with those who produce the building codes.

In addition, a law that will not change behavior as claimed is likely to be the product of special interest lobbying. We might better evaluate whether the law will affect behavior as claimed if we view the activity through an evolutionary lens. In short, a closer look at behavioral biology might help us to better discriminate between public interest and special interest legislation.

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IV. BRAIN PLASTICITY

Professor Jones's emphasis on brain evolution, coupled with a close study of developments in neurophysiology, has the potential to help policymakers better identify those behaviors that are most likely to be influenced by society, education, and law.

As Professor Jones reminds us, our emotions, cognitive capacities, and limitations are all a function of evolutionary forces at work on our brains.[25] We cannot understand or predict human behavior without an understanding of how human brains function as a result of evolution. Important to this understanding is a recognition that natural selection is not a forward-looking phenomenon. Those features that best serve present environments tend to survive, but evolution takes time. A few hundred or couple of thousand years is short, or "present," in light of the brain's much longer evolutionary history. The dramatic and rapidly appearing changes in our environment during the last couple of centuries have outpaced the process of natural selection.

The fact that our brains evolved to deal with earlier times helps to explain the seemingly "irrational" tendencies that have been showing up in the experimental economics and psychology literature, as well as in our every day life experiences. As Professor Jones points out in an important article, our inability to commit ourselves to dieting, our tastes for spite, and our tendency to cooperate "irrationally," all can be attributed to the adaptiveness of these behaviors in the environments surrounding the time period in which we evolved.[26] Moreover, the fact that our brains evolved to deal with context- and environment-specific problems helps explain some common cognitive "failures," including an inability to deal with abstract logical problems, probability assessments, other statistical reasoning, and fine-tuned cost/benefit calculations. When presented with the abstract, or with contexts that are not evolutionarily familiar, our brains tend not to be as good at figuring things out.[27]

Although an understanding of behavioral biology can help us to explain some peculiar cognitive and behavioral predispositions, it is important to keep in mind that the human brain is extraordinarily plastic, and that brain plasticity persists throughout our adult lives. No doubt certain cognitive errors are commonplace, but some people do manage to avoid them, as evidenced by the very fact that we are aware that these errors exist. Casual

25. *Id.* at 838.

26. *See generally* Jones, *Time-Shifted Rationality*, *supra* note 3. *See also* Richard A. Posner, *Rational Choice, Behavioral Economics, and the Law*, 50 STAN. L. REV. 1551, 1561 (1998) (proffering a biological explanation for generosity to strangers).

27. *See generally* Leda Cosmides & John Tooby, *Cognitive Adaptations for Social Exchange*, *in* THE ADAPTED MIND: EVOLUTIONARY PSYCHOLOGY AND THE GENERATION OF CULTURE 163, 181-206 (Jerome H. Barkow et al. eds., 1992) (discussing experimental data indicating that humans perform better when problems are posed in some social context).

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observation indicates that economists rarely commit the sunk costs fallacy, finance professors choose sound retirement plans, tax lawyers are relatively good at calculating present values, logicians impressively solve abstract logical problems, and statisticians are competent Bayesian updaters. Of course, some of these talents are the product of self-selection. Brains, *on average,* are predisposed in particular ways, but individual brains do differ. We thus might expect those good at solving abstract problems to gravitate toward analytical philosophy and those talented in cost-benefit calculations to gravitate toward economics. In addition to inherent individual variation, however, people do learn, and skills improve, thanks to the functional plasticity of the brain.

Section A of this Part will briefly describe some recent studies of human, primate and rodent brain plasticity. Section B will provide important caveats for social efforts to capitalize on brain plasticity to modify behavior. Finally, section C discusses some possible implications of this brain research.

A. *Evidence of Plasticity*

The area of the brain called the neocortex has no sense of pain, so neurosurgeons can operate on conscious patients whose skulls have been numbed with local anesthesia.[28] By stimulating points on the cortex, observing the effects of the stimulation on the patients, and questioning the patients about their experiences, surgeons were able to determine the functions of the various areas of the cortex.[29]

In the somatosensory cortex, there are representations of the skin surface of the entire body laid out as a somatotopic (think topographical) map. This part of the cortex is responsible for processing touch sensations, and the parts of the body are represented not in relation to their relative size but in accordance with their importance in processing touch sensations.[30] The lips and the hand, for example, are allotted more computational space on the surface map than is the back, and scientists think this allotment is highly adaptive for the survival of the animal.[31]

Studies in both adult primates and humans indicate that this cortical mapping in the brain exhibits a significant degree of "functional plasticity," or ability to remap in response to changed circumstances or behavioral needs.[32] I will describe here a few of the studies and their

28. MANFRED SPITZER, THE MIND WITHIN THE NET: MODELS OF LEARNING, THINKING, AND ACTING 105 (1999).

29. *Id.* at 106.

30. *Id.*

31. *Id.*

32. *See, e.g.*, Avi Karni et al., *Functional MRI Evidence for Adult Motor Cortex Plasticity During Motor Skill Learning*, NATURE, Sept. 14, 1995, at 155; Alvaro Pascual-Leone et al.,

findings, and then explain why brain plasticity may be important to a proprioceptive approach to law.

Michael Merzsenich and members of the Coleman laboratory at the University of California, San Francisco, trained adult owl monkeys to either rotate or press on a disc to receive a food pellet.[33] The rotation of the disc stimulated a limited sector of the skin on two to three fingers of these monkeys.[34] The experiment was designed to cause the monkeys to have contact with the disc for approximately 1.5 hours each day for 3.5 months.[35] The experimenters then looked for changes in the cortical representations of the fingers in the brain.[36] For those monkeys that had to press on a flat disc, which took no concentration, there were no changes in cortical representations over time.[37] Monkeys required to rotate a disc had to use the correct amount of pressure and rotate the disc in the correct direction in order to receive a pellet.[38] For this latter group, where more attention was required to complete the task, significant changes showed up in the cortical representations.[39] The cortical representations of the stimulated skin surfaces expanded to an area 1.76 to 2.71 times larger than the representation area in the control mappings.[40] In addition, experimenters discovered that the receptive fields recorded were unusually small.[41] Representational discontinuities emerged, and the borders of the hand representation expanded into the neighboring face representation.[42]

These changes in the monkeys' brains corresponded to an increased ability to use their fingers and to discriminate stimuli to the fingers.[43] A similar change happens to human ballet dancers, who develop a much more elaborate use of their feet than the rest of use who walk around flat-footed and bundled in shoes. In the case of the owl monkeys, the expanded

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Modulation of Cortical Motor Output Maps During Development of Implicit and Explicit Knowledge, 263 SCI. 1287 (1994); G.H. Recanzone et al., *Plasticity in the Frequency Representation of Primary Auditory Cortex following Discrimination Training in Adult Owl Monkeys*, 13 J. NEUROSCIENCE 87 (1993); Ehud Ahissar et al., *Dependence of Cortical Plasticity on Correlated Activity of Single Neurons and on Behavioral Context*, 257 SCI. 1412 (1992); H. Aizawa, *Reorganization of Activity in the Supplementary Motor Area Associated with Motor Learning and Functional Recovery*, 84 EXPERIMENTAL BRAIN RES. 668 (1991); William M. Jenkins et al., *Functional Reorganization of Primary Somatosensory Cortex in Adult Owl Monkeys after Behaviorally Controlled Tactile Stimulation*, 63 J. NEUROPHYSIOLOGY 82 (1990).

33. Jenkins et al., *supra* note 32, at 85.
34. *Id.* at 86.
35. *Id.* at 89.
36. *Id.* at 82.
37. *Id.*
38. *Id.* at 86.
39. *Id.* at 89.
40. *Id.*
41. *Id.* at 82.
42. *Id.* at 89.
43. *Id.* at 102.

representational areas shrank when no longer used.[44] Significant shrinking was observed thirty-one days after the disc exercises ended, and further shrinking was observed sixty-three days after the exercises ended.[45]

The cortical plasticity finding has been replicated in various studies, but I will mention only a few more here. Experimenters surgically fused two of the fingers of owl monkeys, which resulted in behavioral synchronicity of the fused digits.[46] In a relatively short period of time, the normally abrupt border between the two digits was eliminated in the cortical mapping of these monkeys.[47] In the mapping, the fingers were represented in the same manner in which they were now being used, as though they were a single digit.[48]

Moreover, when part of an arm is amputated, the surrounding cortical representations of the body's surface are extensively remapped, overlapping into the area previously occupied by the amputated part.[49] In fact, studies indicate that this remapping may explain what is known as the "phantom limb" phenomenon.[50] According to patient reports, amputees often continue to feel, or sense, the hand, arm, breast, or leg that is no longer there.[51]

In a study at University of California, San Diego, humans who had lost all or part of an arm were stimulated on the face and at the skin area of the arm just above the amputation.[52] These two areas of the skin border the amputated portion of the arm in the cortical representation.[53] Some of the subjects reported that they simultaneously "felt" the stimulation on both the actual skin surface touched and some part of the missing limb.[54] This double sensation is likely attributable to the fact that the neighboring cortical representations are overlapping the location where the amputated arm had been previously represented.[55]

The phantom limb reports may parallel more complex phenomena such as grieving. Casual observation indicates that those who are grieving the

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44. *Id.* at 91.

45. *Id.* at 93.

46. *Id.* at 82-83.

47. *Id.*

48. *Id.*

49. *See generally* V.S. Ramachandran, *Plasticity in the Adult Human Brain; Is There Reason for Optimism?*, *in* MATURATIONAL WINDOWS AND ADULT CORTICAL PLASTICITY 179 (B. Julesz & I. Kovács eds., 1995).

50. For a discussion of phantom limbs, successful treatment, and its implications for theories of the brain, see V.S. Ramachandran et al., *Illusions of Body Image: What They Reveal About Human Nature*, *in* THE MIND-BRAIN CONTINUUM 29, 30-37 (Rodolfo Llinas & Patricia S. Churchland eds., 1996).

51. *See generally id.*; Ramachandran, *supra* note 49.

52. Ramachandran, *supra* note 49, at 183-84.

53. *Id.* at 182.

54. *Id.* at 180-83.

55. *Id.* at 181.

loss of a loved one continue to "function" for awhile as though the individual is still alive. Intellectually, the griever can articulate that the deceased is no longer alive, but the griever nevertheless finds himself waiting for the telephone to ring or the door to open. The widow spends a period of time leaving her husband's side of the bed vacant and continues to make decisions that the absent spouse would have approved. Is it possible that our relationships with those we love are somehow mapped onto the brain so that severing those relationships becomes temporarily difficult in part because of the time it takes to achieve a remapping? In the end, we do not forget what that relationship "felt" like, but we do learn to allow other things to take over its space. Can it be said that grieving and healing is an example of functional plasticity?

Studies of cortical plasticity suggest that a certain amount of attention is required to induce changes in brain mapping, at least with respect to stimuli without the brain.[56] Studies also indicate that significant improvements in functional plasticity require a combination of "active" behavior, coupled with thought, concentration, and reward or motivation for behavior (which may induce the concentration).[57]

For example, scientists in Israel used adult monkeys to study the firing of neurons and the causes of improved synaptic plasticity.[58] In their experiment, one group of monkeys was given an auditory discrimination task.[59] These monkeys were presented with differing sounds, and, if a monkey responded to the correct one, it received a drop of juice.[60] A second group of monkeys received the same sequence of sounds but did not perform the task or receive a reward.[61] A third group received juice, but randomly in response to a random sequence of sounds.[62] The monkeys in the first group, those who received conditioning associated behavior, exhibited by far the strongest improvement in connection between the firing of interacting neurons.[63] In many cases, the monkeys exhibited no neuronal plasticity at all without the combination of a pattern requiring concentration plus a reward.[64]

Other studies of adult primates and humans not only have produced results consistent with the study in Israel but also have shed further light on how people learn. A lab in Japan trained adult monkeys to perform simple key press movements in response to visual stimuli.[65] If the monkeys

56. *See, e.g.*, Karni et al., *supra* note 32, 155.
57. *See, e.g.*, Ahissar et al., *supra* note 32, 1412.
58. *Id.*
59. *Id.*
60. *Id.* at 1413.
61. *Id.*
62. *Id.*
63. *Id.*
64. *Id.* at 1414.
65. Aizawa, *supra* note 32, at 668.

saw a right light illuminate, then they were to press the right button.[66] If they saw a left light illuminate, they were to press the left button.[67] Each monkey that pressed the correct button was rewarded.[68] When the monkey was trained for a relatively short period of time—up to four months—scientists observed neuronal activity in the associated supplementary motor area before the monkey moved its limb.[69] However, when the monkey was trained for twelve months, the premovement activity in the supplemental motor area disappeared.[70] The authors think that the brain eliminates redundancy over time, because the same neuronal activity occurs in the primary motor cortex.[71] Once a task becomes overlearned, they hypothesize, the brain reduces redundancy to enable more efficient information transmittal and to make way for higher level, more complex activities.[72] We can view the shift from the supplementary motor area to the primary motor cortex as the equivalent of habit formation, which works much like our morning drive to work on autopilot.

The same experimenters then lesioned the primary motor cortex of the monkeys, allowed a three-week recovery period, and retrained the monkeys on the key press.[73] The premovement neuronal activity reappeared in the supplementary motor area.[74] These results again indicate the highly plastic nature of the brain, which responds very much to both behavior and to changes within the brain.

Another study of human adults indicates that the brain treats information during a learning process differently from the way it treats actually acquired knowledge.[75] The experiment involved sequential finger movements.[76] The subjects were placed in front of a computer with a "mouse" that had four buttons.[77] Each finger was assigned to one of the four buttons.[78] When a number showed up on the screen, the subject was asked to press the appropriate button with the appropriate finger.[79] The number remained on the screen until the subject successfully completed the task, at which point the time taken to complete the task was recorded.[80]

66. *Id.*
67. *Id.*
68. *Id.*
69. *Id.*
70. *Id.*
71. *Id.* at 668, 670.
72. *Id.* at 671.
73. *Id.* at 669.
74. *Id.* at 670.
75. *See generally* Pascual-Leone et al., *supra* note 32, at 1287.
76. *Id.*
77. *Id.*
78. *Id.*
79. *Id.*
80. *Id.*

This sequence occurred 120 times, then the subject took a break, then the subject received 120 more numbers, followed by a break, and so on.[81]

The subjects were broken into two groups.[82] The control group was given a random sequence of numbers.[83] The test group was given a sequence of twelve numbers repeated ten times (i.e., 124432123341).[84] At the end of each batch of 120 trials, each subject was asked whether he thought the order of numbers was random or patterned.[85] If a subject thought that the numbers were patterned, then he was asked to articulate the pattern.[86] The study compared the development of "implicit" and "explicit" knowledge.[87] Implicit knowledge involves the correct awareness that there is a pattern but an inability to construct that pattern.[88] Explicit knowledge requires that the subject be able to articulate the pattern.[89] While the tasks were performed, experimenters mapped the cortical motor outputs to the muscles involved in the task.[90]

Performance during the first block of 120 numbers was the same for both groups.[91] Across blocks, the control group response times remained stable, and there was no change in the mapping of cortical outputs to any of the muscles for this group, so long as the practice sessions lasted for less than two hours each day.[92] In contrast, the test group had progressively shorter response times and exhibited progressively larger maps of the cortical outputs to the muscles involved in the task.[93] After four batches, the subjects' mean response time was approximately one-third of that of the original batch, and there were significant increases in the mapped areas as well as an increased amplitude of neuronal activity.[94] At this point, all test subjects had figured out that they had been given a non-random pattern, but no one could yet articulate that pattern.[95] In other words, the test subjects had acquired implicit knowledge.[96]

The cortical output maps to the muscles involved in the task became progressively larger until explicit knowledge was achieved, which

81. *Id.*
82. *Id.*
83. *Id.*
84. *Id.*
85. *Id.*
86. *Id.*
87. *Id.* at 1288.
88. *Id.* at 1287.
89. *Id.*
90. *Id.*
91. *Id.*
92. *Id.*
93. *Id.*
94. *Id.*
95. *Id.*
96. *See id.*

occurred in six to nine batches, depending on the subject.[97] After explicit knowledge was achieved, the output maps returned to their baseline topography, but response times continued to fall down to one-sixth of the original time.[98] At this point, the subjects were no longer reacting to the number signal but were instead anticipating it.[99] To the authors, the results suggest that as a motor sequence is explicitly learned, the contribution of the motor cortex is attenuated and other brain structures assume a more active role in the execution of the task as a skill becomes overlearned or automatic.[100] If so, the study provides further evidence that the brain functions in a plastic and relatively efficient manner.

Neurophysiologists have also confirmed that functional plasticity, at least as it relates to cortical representations, continues into old age.[101] A study of rats and aging found significant physical changes in the brain that correspond to the changing use of the rats' legs as they age.[102] Young rats walk only on the pads of their feet, while the hind part of the leg of old rats falls and dragging in their steps is common.[103] When the somatosensory hindpaw representations of the two groups were compared, scientists observed enlarged receptor fields for the old rats covering multiple areas, which corresponds to the increased leg use and dragging.[104] Moreover, fine distinctions and gradations in these representations had broken down, which corresponds to the decreased functionality of the foot pads.[105] The cortical topographies overlapped and became jumbled as a result of the overlapping representations.[106] These brain differences were not a function of age alone.[107] Old rats that walked like younger rats did not exhibit these representational changes in the brain.[108] The brain changes appear to be a response to differing behavioral stimuli, and they appear to occur even at very old ages.[109]

97. *Id.*
98. *Id.*
99. *Id.*
100. *Id.* at 1288.
101. *See* M.M. Merzenich & R.C. deCharms, *Neural Representations, Experience, and Change*, *in* THE MIND-BRAIN CONTINUUM 61, 62 (Rodolfo Llinas & Patricia S. Churchland eds., 1996) (concluding that "[i]t is now clear that the brain is malleable throughout life").
102. F. Spengler et al., *Effects of Aging on Topographic Organization of Somatosensory Cortex*, 6 NEURO REP. 469, 469-70 (1995).
103. *Id.*
104. *Id.* at 473.
105. *Id.*
106. *Id.*
107. *Id.*
108. *Id.*
109. *Id.*

B. *Behavior Modification and Caveats*

This plasticity is fascinating, and the research may someday prove promising for our attempts to encourage and teach law-abiding, cooperative behaviors. After all, if environments can change the physical structure of the brain, both predictably and efficiently, then presumably environments can affect both our thinking and behavior in important ways. Moreover, if plasticity continues through adulthood, then perhaps socially relevant behaviors are also always subject to some change at the margins. Competition within the brain for space depends on behavior, practice and motivation, which means that there is a cost to changing our patterns of thought and action. Moreover, the phantom limb studies reinforce our instinctual belief that old habits die hard. But, these studies also indicate that habits can be replaced functionally, even if they are never forgotten.

There are several potential problems, however, with the idea that we can manipulate environments to change the physical structure of the brain (even assuming that structural changes ultimately contribute to behavioral changes). First, we need to know more about critical periods.[110] Although our knowledge of the brain is growing at an astounding rate, we are still ignorant about much of higher level learning. For some brain development, critical periods allow only a limited window for plasticity.[111] Some abilities and skills, including eyesight and language development, are triggered only or primarily in children.[112] Moreover, neuronal degradation

110. As Gilbert Gottlieb has explained,

> There are prenatal and postnatal periods or stages in development when the organism is dependent on certain forms of stimulation for subsequent normal (typical) development. Other ways of viewing these stages are that they are ones in which the organism is maximally susceptible to certain kinds of stimulation, or when ease of mastering certain behavioral traits is much higher than at other times in the life cycle. These stages are sometimes referred to as critical periods of development. . . . On its weakest interpretation, the concept of an optimum or critical stage implies that the development of particular abilities or endpoints is not equipotential over the lifespan; on its strongest interpretation, the critical period concept means that certain experiences must occur during a delimited period early in development if subsequent development is to be normal (species typical).

Gilbert Gottlieb, *The Psychobiological Approach to Developmental Issues, in* INFANCY AND DEVELOPMENTAL PSYCHOBIOLOGY 6, 7 (1983) (Marshall M. Haith & Joseph J. Campos eds., 1983).

111. *Id.*

112. Paula Tallal et al., *Language Comprehension in Language-Learning Impaired Children Improved with Acoustically Modified Speech*, 271 SCI. 81, 83 (1996).

in the elderly affects memory and other performance-related skills in ways that may limit our ability to influence them.[113]

Second, some learning is permanent, but some is only temporary, and some brain changes occur only under behavioral stimuli. Even temporary changes require both behavior and a motivation to attend to that behavior.[114] Although potentially limiting as a social tool, these advances in brain science confirm the belief of many that the important lessons in life require the active involvement of the subject. After unsuccessfully preaching to teenage girls about the costs of young motherhood, some teachers created the experience for the girls.[115] Teachers handed each student a bundle that she could not drop or leave alone for a few days. During this period, the girls found their bundles making loud noises in the middle of the night, during their television programs, and in the midst of their socializing with friends.[116] The girls turned their bundles back reporting a new appreciation for the importance of responsible sexual behavior.[117] Perhaps these insights can tell us more about the effectiveness of community service and alternative ways to present driver education materials.[118]

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113. *See* Spengler et al., *supra* note 102, at 469.

114. *See* Merzenich & deCharms, *supra* note 101, at 71 ("Cortical plasticity is induced by learning, but not when equivalent stimuli are delivered to a nonattending animal, or when there is not an appropriate source of cognitive drive (reward, punishment, novelty, etc.) in the behavior.").

115. *See, e.g.*, Jane J. Russel, Editorial, *And, Baby, Did She Think This Over,* SAN ANTONIO EXPRESS-NEWS, May 17, 2001, at 7B (describing a weekend assignment for school health class); Tammy L. Carter, *Baby Was a Boomer—And a Lesson,* ORLANDO SENTINEL, May 17, 2001, at E1 (describing a project of an eighth grade science teacher); Karen Klinka, *Bringing Up "Baby": Students Find Caring for Baby a Challenge,* DAILY OKLAHOMAN, May 14, 2001, at 1 (describing a Catholic high school assignment); Lynn Seeden, *Baby, Think It Over,* ORANGE COUNTY REGISTER, June 7, 2001, at 1 (describing a high school student project); Rosa Salter, *Sacks of Flour Made Couple Come Up With a Better Baby,* ALLENTOWN MORNING CALL, June 24, 2001, at H2 (reporting that over 1 million teens have used the baby simulators). One study attempted to track the effectiveness of the baby simulator programs. Charyl L. Somers & Mariane M. Fahlman, *Effectiveness of the "Baby Think it Over" Teen Pregnancy Prevention Program,* J. SCH. HEALTH, May 1, 2001, at 188. Seventy-nine percent of the teenagers polled said that the baby simulator made them more concerned about becoming pregnant. When students given the baby simulators were compared to a control population, however, the students with the simulators did not experience a statistically significant reduction in teen pregnancy. The study cites methodological flaws as possible explanations. Interestingly, the authors thought that one weekend might have been too short a period of time for the program to have a lasting effect. *Id.* at 192.

116. *See generally* sources cited *supra* note 115.

117. *See generally* sources cited *supra* note 115.

118. It is also important to reach teenagers early. Plasticity exists in most aspects of brain development at least through puberty, which means that the environment of young people matters significantly. Julia A. Graber & Anne C. Petersen, *Cognitive Changes at Adolescence: Biological Perspectives, in* BRAIN MATURATION AND COGNITIVE DEVELOPMENT: COMPARATIVE AND CROSS-CULTURAL PERSPECTIVES 253, 274 (Kathleen R. Gibson & Anne C. Peterson eds., 1991). And, although brain plasticity does exist throughout adulthood, the effects of environment on the brain may become less marked as time passes. Advances in knowledge about brain maturation eventually

A third difficulty with attempting to promote specific social behavior is the fact that some cognitive and motor improvements are highly specific to the task trained and have not proven to be generalizable to other contexts. Consider, for example, one study that involved training in a finger-tapping sequence.[119] Subjects practiced their tapping for ten to twenty minutes each day for three weeks, and by the end, they had more than doubled their initial rate of completion and their accuracy improved significantly.[120] These skill improvements lasted for several months with no additional training.[121] The training resulted in both improved synaptic connections and enlarged cortical representations.[122] Unfortunately for our purposes, these improvements were confined to the specific hand trained and did not carry over to the other hand.[123] Moreover, the learning did not generalize to new sequences, even though the new sequences were made up of identical component movements.[124]

Fourth, some efforts to teach social behaviors can be limited by the potential for deafferentiation. Deafferentiation occurs when subjects repeat tasks with stereotypy, or little variety. In these circumstances, the individual attends to his behavior, but the lack of variety in that behavior leads to performance inabilities over time. Musicians, for example, can suddenly find themselves unable to move their hands in the manner necessary to play their instruments well. The neurophysiology of deafferentiation appears similar to the cortical representation changes for older rats. In both circumstances, the relevant cortical representations expand, but instead of the finer gradations and clear borders between sensory areas that are seen with the honing of a motor skill, these representations become essentially undifferentiated. Deafferentiation can lead to focal dystonia, or an inability to move parts of the body (i.e., fingers) separately. Thus, the regimentation, or overlearning of certain behaviors, can cause a degradation in the feedback information, which can ultimately lead to an inability to fine-tune the behavior in question. Perhaps there is some parallel here to moral teachings that take the form of stylized, repetitive chanting.

Finally, and most importantly, any efforts to change social behaviors must confront the fundamental lessons contained in the work of Professor Jones. Our brains are the result of evolutionary forces, and some of those forces are more powerful than others. We can train people to make better cost-benefit analyses and we can teach them to solve abstract logical

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may help us to draw the lines between the juvenile and adult justice systems more precisely.

119. Karni et al., *supra* note 32, at 155.

120. *Id.* at 155-56.

121. *Id.* at 155.

122. *Id.* at 158.

123. *Id.* at 156.

124. *Id.*

problems. But we may not be able to teach them selflessness, non-jealousy, or non-materialism. Furthermore, these changes are inevitably costly, and the price may be too high in some cases but not in others. Those trained in economics always look for trade-offs, and the same must be true for behavioral biology. My goal here is simply to point out that plasticity and evolution counterweigh each other, and neither should be ignored when fashioning legal decisions. I am confident that Professor Jones agrees.

C. *Legal Implications*

How much can neuroscience tell us about the law and its role in influencing human behavior? The scientific research remains focused on very basic forms of behavior, and much of that research involves other species. Because research on brain plasticity is still in its very early stages, and humans are wonderfully complex creatures, any suggestions about the relationship between the science and the law will seem wildly speculative. Nevertheless, if the connection is plausible, then it is worthwhile to follow future developments in neuroscience because that knowledge might edify our efforts to use the law as productively as possible. My goal here is to convince the reader that there are plausible, if speculative, connections between brain plasticity research and the law. Moreover, I intend what follows to be illustrative rather than exhaustive of possible connections.

That said, a focus on the tradeoffs between evolutionary biology and brain plasticity might help us to understand how law is, and perhaps should be, designed. Consider, for example, the distinction between criminal and civil negligence in our legal system. One of the purposes of our civil negligence system is to encourage people to take care to avoid harming others, but we also want to encourage people to take the optimal amount of care, which requires them to think about the costs of harm and of safety efforts. If in fact we use the civil negligence system to encourage people to make more precise calculations of expected costs and benefits, then a better understanding of brain plasticity and its limitations aids our determination of the proper negligence standard for criminal law. If culpability is essential to criminal convictions, then we must be careful not to condemn those who had difficulty making a cognitive calculation that is generally difficult for humans. The civil law encourages people to practice thinking about these calculations, but if everyday life provides insufficient practice to increase significantly our skills, then we might reserve criminal negligence only for people whose miscalculation represent a gross deviation from the standard of care we impose in our civil system.[125] If, however, professionals and experts engage in potentially

125. *See generally* Jeffrey S. Parker, *The Economics of Mens Rea*, 79 VA. L. REV. 741 (1993)

harmful behavior on a repeat basis, then we might expect them to be better at calculating the costs and benefits of their activities than would a lay person. Criminal negligence may therefore be more appropriate for professionals than for lay individuals.

Judges and juries should also find some claimed eye-witness testimony more credible than others. External stimuli must compete for attention by the brain, and the brain has evolved to pay attention first to new facts that are important to the well-being of the individual. We are most likely to notice whether a visitor has a gun in his hand or whether a woman had an appealing physique. We are less likely to notice the color of a person's eyes or the page number in the book we are reading. And similar reasoning must be true for mistakes of fact. Lessons from brain plasticity remind us, however, that experts are better able to capture some information than others. An accountant, for example, is more likely to find a reporting error than is the lay individual, so that the lay person's "mistake" may be more credible than the accountant's.

The limited mistake of law defense to criminal law may also make sense in light of what we now know about the brain. In the past few decades we have witnessed a proliferation of complex regulatory statutes that are often strengthened with criminal sanctions. When those complex statutes touch our lives, the information burden on the average person is probably more than we can reasonably be expected to bear. The mistake of law defense has been used in these circumstances to either excuse those of us who did not know our legal obligations or to require the government to subsidize our costs of obtaining information about the law.[126] Interestingly, the mistake of law defense, in effect, is narrowly cabined to disallow repeat players from using the defense.[127] These individuals have enough contact with the regulation to be easily trainable with regard to their intricacies.[128]

Somewhat relatedly, we know enough about the brains of the elderly now to acknowledge that simple regulations and choices are probably better than more complex ones.[129] For example, a nuanced health care program better enables an elderly individual to choose those features that best suit her needs. Unfortunately, however, nuanced health care systems

(discussing mens rea and the efficiency implications of placing information burdens on criminal defendants).

126. For a discussion of cases requiring the government to provide information to potential defendants, see Richard S. Murphy & Erin A. O'Hara, *Mistake of Federal Criminal Law: A Study of Coalitions and Costly Information*, 5 SUP. CT. ECON. REV. 217, 265-70 (1997).

127. *See id.* at 260-61 (discussing how enforcement efforts and appellate review standards work together to filter defendants in criminal tax prosecutions).

128. *See id.* at 256-57 (explaining that no mistake of law defense is available for industry regulations).

129. For a discussion of the biology of aging and its legal implications, see generally RICHARD A. POSNER, AGING AND OLD AGE (1995) and sources cited therein.

can be quite complex, and those complexities can make it difficult for the elderly to understand fully the choices that they are making. The latter concern turns out to be more problematic than we had previously thought, given that fine-tuned distinctions appear to be among the first victims of neuronal degradation. Of course, the program fit must be weighed against the difficulties of processing complexities, but the proper balance likely entails more simplicity than it would for younger adult decision makers.

The tension between evolutionary forces and plasticity in the brain is also relevant to the debate between economists and criminal lawyers regarding the effectiveness of deterrence. Some criminal lawyers contend that deterrence does not work. Criminals continue to commit crimes no matter what the penalty while non-criminals refrain from criminal behavior even when no one is observing them. In contrast, some economists contend that if you raise the price of criminal activity, it must be that less of it is demanded by potential offenders. Despite empirical efforts by members on both sides of this debate to prove the correctness of their views,[130] a nuanced interpretation of the facts seems to indicate that some but not all crimes are significantly affected by marginal deterrence efforts. More specifically, violent crimes seem to be less responsive to small changes in punishment or the probability of conviction than are non-violent crimes.

From the perspectives of behavioral biology and neurophysiology, this result makes sense. Human emotions are a result of evolutionary forces, and violent behaviors tend to be those that are most closely aligned with these forces. On the other hand, repeat behaviors are subject to more careful cost-benefit calculations. White collar crimes and black market activities make up a significant portion of non-violent crimes, and these individuals are likely relatively good at calculating the costs and benefits of their criminal activities and acting accordingly. If so, then at the margin this group of potential crimes is more likely to respond to law enforcement efforts.

Interestingly, as a society we may want potential offenders to make more precise cost-benefit calculations in some situations but less precise calculations in others. We might wish to send the message that it does not pay to speed in a work zone while at the same time asserting that other behaviors are just plain wrong. We teach children from a very young age

130. *E.g., compare* Daniel Kessler & Steven D. Levitt, *Using Sentencing Enhancement to Distinguish Between Deterrence and Incapacitation*, 42 J.L. & ECON. 343, 359 (1999) (arguing that sentencing enhancement increased deterrence) *and* Raymond A. Atkins & Paul H. Rubin, *Effects of Criminal Procedure on Crime Rates: Mapping Out the Consequences of the Exclusionary Rule*, (Oct. 23, 1998), *available at* http://www.ssrn.com/sol3/papers:cfm? abstract_id=140992 (arguing that an increase in crime has followed the adoption of the exclusionary rule), *with* MICHAEL TONRY, SENTENCING MATTERS 137 (1996) (suggesting that government officials are concluding increased penalties do not reduce crime).

that all drugs are bad and likely to kill them. And the ten commandments are repeated over and over in Sunday school. It may be that some crimes are more easily averted by getting people to focus on cost-benefit calculations while others are more easily averted by taking advantage of cognitive weaknesses. If we overlearn the golden rule, propaganda, and social memes, then we might just affect a type of deafferentiation within the brain. People are unable to make fine-tuned distinctions about right and wrong, but with deafferentiation we are better able to eradicate the wrong.

In contrast, overdeterrence becomes a potential problem for malum prohibitum crimes. These criminal statutes prohibit behavior that is not inherently wrongful, so conduct close to the line of criminality may be socially useful and worthy of protecting. Tax deductions are an example. Certain deductions are impermissible, whereas others are not only permitted, they are encouraged. In these contexts, society might well want people to make fine-tuned distinctions between permitted and prohibited acts. We might therefore expect that effective law enforcement propaganda will encourage taxpayers to weigh carefully the costs and benefits of their activities.

V. CONCLUSION

Owen Jones's excellent Dunwody Lecture is rich, original and thought-provoking. I have no noteworthy suggestions for its improvement. Instead, this response offers two admittedly speculative suggestions for future research topics in biolegal history and for law and the behavioral sciences generally.

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