Optimizing Engines: Rational Choice in the Neolithic?

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This article has both substantive and methodological goals. Methodologically, it shows that rational choice theory (in its behavioral ecology form) is an especially important tool for guiding research in contexts in which agents appear to be acting against their best interests. The Neolithic transition is one such case, and the article develops a substantive conception of that transition, illustrating the heuristic power of behavioral ecology.

1. Irrational Choice in the Neolithic? This article has both a substantive and a methodological agenda. Substantively, it aims to improve our understanding of an especially puzzling feature of human social life: the origins of complex, settled society and the shift from foraging to farming, beginning about 13,000 years ago, in the Levant and its surrounds. The methodological aim is to display the strengths of human behavioral ecology when faced with apparently paradoxical forms of behavior. As we shall see, it is difficult to explain the origins of agriculture in terms of individual benefit, and as a consequence, there has been an expansion of collective benefit models of this evolutionary transition (Bowles and Gintis 2011). For reasons developed elsewhere, I am skeptical of those collectivist models (Sterelny 2014). But even if they were defensible, empirical testing is typically comparative, and

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competing models expose each other's distinctive empirical commitments, so individualist models are still worth developing.

The shift to settled society is puzzling because it seems to have involved profoundly paradoxical decisions: a more labor-intensive life, tolerating inequality, and heavy investment in apparently wasteful activities. How to explain these patterns? Impressive approaches to human behavior, one with an origin in economics and the other with its origin in evolutionary biology, converge in treating human action as optimizing in the face of tradeoffs between competing demands for resources, and despite the requirement to act in a dynamic environment in which the results of one's own choice often depend on the choices of others. These models represent agents as facing a set of options, with some but not perfect information about the outcome of each choice (imperfect in part because these outcomes depend on others' choices). They must weigh risk against potential payoff, and they choose the best risk-weighted option. In the economic tradition, these payoffs are material; in the biological tradition, they are effects on the agent's biological fitness. To the extent that material resources contribute to fitness, these two approaches converge.

Can this conception of action illuminate one of the most profound changes in our history—the shift from a life of foraging to life in a built world, producing rather than gathering food, surrounded by others doing the same? This article aims both to exhibit the heuristic power of this optimizing approach and to make progress in solving some of the substantive puzzles about the transition.

I shall begin by explaining the prima facie strength of the constrained optimization approach to human action, but before doing so, I have inserted a table giving readers a road map to the periods and places in question (see table 1). Both dates and labels vary a little from source to source; this version is from Watkins (2010). The critical period for this article is probably from the Natufian through the Pre-Pottery Neolithic A (PPNA). By the beginning of the Natufian, there are signs of a significant shift to a more sedentary life, but one probably depending on wild resources. In the same re-

TABLE 1. Stages in the Neolithic Transition

Periods	Approximate Dates	Levant Label
Upper Palaeolithic	45,000–25,000 BC	
Early Epipalaeolithic	23,000–15,000 BC	Kerbaran
Middle Epipalaeolithic	15,000–13,000 BC	Geometric Kerbaran
Late Epipalaeolithic	13,000–10,200 BC	Natufian
Early Aceramic Neolithic	10,200–8,800 BC	PPNA
Late Aceramic Neolithic	8800–6900 BC	PPNB

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gion, by the end of the PPNA, people are becoming dependent on food they produce themselves, and they are living in substantial structures in settled communities.

Human behavioral ecology imports formal tools and conceptual frameworks from evolutionary biology to human behavior and its evolution. This toolkit is impressively diverse, including multilevel selection, niche construction, life history theory, and evolutionary game theory. But optimality analysis is one important, simple, and powerful tool. These analyses explain human action by showing that in regular patterns of human decision making, agents maximize their individual fitness, given the options they face (for recent reviews, see Laland and Brown 2011; Mulder and Schacht 2012, and references therein). Obviously, even in life-or-death situations, the first time an agent encounters a novel problem, wise choice is far from guaranteed. But when agents with relevant experience make decisions that matter, they are optimizing engines, though their decisions are constrained by their own resources; the cost of, and access to, information; the decisions of others; and the social, biological, and physical environment.

Human behavioral ecology has shown its power in, for example, the debates over the role of large game hunting in forager life. Its toolbox does not settle the debate, but it identifies the information we need. If hunting is essentially family provisioning, with sharing as a form of insurance, sharing should be contingent on both return from others and the extent to which success and failure depend on factors outside an agent's control. To the extent that hunting and sharing are sustained by indirect reciprocal benefits, these should flow to the family of the hunter, not just the hunter himself. If instead hunting is costly signaling, there is no reason to expect that sharing is contingent on direct reciprocation or uncontrollable risks (Hawkes and Bird 2002; Gurven and Hill 2009; Hawkes, O'Connell, and Coxworth 2010). Such information is hard to find, but human behavioral ecology tells us what to look for.

Importantly, optimality thinking is productive, even though agents are in fact not optimally adapted to their environment. Indeed, a main theme of this article is that human behavioral ecology can be especially valuable when used to probe apparently maladaptive or puzzling behavior, such as food taboos or female acquiescence in polygamous marriage. For such seemingly paradoxical behavior can reveal unobvious constraints on choice, hidden costs of (apparently) beneficial choices, hidden benefits of (apparently) maladaptive choices, lack of access to crucial information, and mismatch between proximate motivation and the sources of fitness (as in, e.g., Mace 1998). Thus, apparent model failures can be especially informative. The Neolithic transition in southwest Asia is especially rich in such apparent failures. At or near the Pleistocene-Holocene boundary, human life began to change dramatically, as human mobility declined, and as humans began to farm both plants and animals and to use pottery and polished and ground stone tools. Perhaps most

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importantly, they began to live in larger and more complex social units. These changes were once collectively known as the Neolithic Revolution (Childe 1936). It turns out that the classic Neolithic package of domestication (of plants and animals), storage, a sedentary lifestyle, and craft specialization is neither Neolithic nor a package. Some of these traits had their origins deep in the Epipalaeolithic, and others, like pottery, became important only in the late Neolithic (Watkins 2005; Verhoeven 2011). Moreover, the classic package leaves out other changes that are as important: increased investment in ideological infrastructure; life in an increasingly built, human-made environment; life in larger social groups; and groups embedded in a spatially extended interaction zone, with trade playing a much more important role in material culture. So the "Neolithic package" is larger, but perhaps less tightly integrated, and with origins spread over a longer time frame. Even so, Childe was right to identify a profound social transition here.

Moreover, from the perspective of human behavioral ecology, it is a transition rich in apparent paradox. In particular, we can document three puzzling patterns of behavior in the Levant and surrounding areas. The first is the shift from mobile foraging to farming. Once farmers became dependent on a few key crops, they were exposed to risk through their narrow resource base, their dependence on storage, and their sunk costs in land and its preparation. Moreover, the per-hour rate of return is low (Asouti and Fuller 2013), and subsistence farming is hard, unpleasant work. Thus, farmers often exploit coerced labor: wives, children, and slaves (Cohen 2009). In contrast, hunters like hunting: that is one reason why Hawkes suspects that it is not merely an economic activity. Marshall Sahlins made this problem vivid, pointing out that mobile foragers are typically healthy, are time rich, and have effective risk management strategies (Sahlins 1968). Subsequent research has not changed those conclusions qualitatively. The most obvious response is that farming is a forced choice. Foragers are driven to low-return activities by an increasingly unfavorable ratio of population to resources (for a classic exposition of this argument, see Flannery 1969). This natural thought turns out to be difficult to vindicate empirically.

Our second puzzle is centered on the shift from egalitarian societies to transegalitarian[1] and then stratified societies, with the consequence of increasing inequality, as aggrandizers seize an increasing share of resources. The problem here is not aggrandizer motivation but commoners' acquiescence. Forager societies were egalitarian through the active enforcement of norms of sharing and modesty (Boehm 1999, 2012).[2] Transegalitarian so-

1. That is, societies that have developed significant inequalities, but where these inequalities have not been institutionalized as formal ranks.

2. I here assume that the ethnography of mobile foragers is a reasonable guide to basic features of Palaeolithic forager groups (see Shultziner et al. 2010; Boehm 2012).

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cieties emerge out of cultures in which it was in the interests of (most) agents to control aggrandizers, societies in which agents had the capacity to control aggrandizers and were primed to do so. What explains the failure of collective action in defense of those common interests?

That second puzzle is intensified by clear evidence that these groups were capable of high-cost collective action. For our third paradox is increasing collective investment in ideological infrastructure. The ideological life of the neolithicizing peoples became increasingly—outrageously—expensive. The standout case is Gobekli Tepe, a site in northern Levant established around the beginning of the Neolithic.[3] It seems to be an ideological center of some kind. The structures there are enormously impressive and expensive: they include huge stone slabs (sometimes more than 5 meters tall), often intricately and exquisitely carved. Moreover, these monuments were sited in chambers dug deep into a mound of debris, and these chambers needed to be excavated and stabilized. Gobekli Tepe is unique in being so early, specialized for ideological activity, and monumental (hence extraordinarily expensive). But it is by no means the only example of heavy investment in nonutilitarian activity in the late Epipalaeolithic and early Neolithic (Stordeur 2000; Mithen et al. 2011).[4] Why were these people laboring on stone (probably in the hot sun), when they could be feeding or fornicating?

Prima facie, then, the typical Neolithic agent behaved increasingly strangely: forsaking the benefits of mobility and a broad resource base to work harder for less, at greater risk; acquiescing in social and economic subordination; and directly or indirectly supporting the grossly wasteful expenditure of the social surplus. The first of these puzzles has been discussed extensively and explicitly in the archaeological literature; the other two have been less clearly identified. In the rest of this article, I aim to show the power of the individualist, optimizing framework: (1) it helps us identify the problematic aspects of the transition, (2) it suggests plausible hypotheses, and (3) it identifies crucial evidential gaps in our picture of the transition. I begin with the problem of farming.

3. The spectacular structures date to early PPNA, about 11,500 BP, but the site itself is older (Dietrich et al. 2012).

4. Investment in monumental structures, in fact, seems to be quite a pervasive feature of the transition to sedentary social environments, though in most places in the world, this transition took place well into the Holocene: there is evidence of it in North America, Central America, South America, and China (Hass and Creamer 2006; Coon 2009; Renfrew 2013; Zhang, Bevan, and Guo 2013). In some places, these monumental sructures seem to be associated with competitive interactions between larger social groups (Coon 2009), but in others, as at Gobeke Tepe, we see large-scale investment in ideological infrastucture but without any signs of group-group conflict (Hass and Creamer 2006). I return to this point and its significance in the final section.

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2. Farms, Feasts, and Signals. Though the pattern of domestication is becoming known in increasing detail (Zeder 2011), there is still no consensus causal model (Price and Bar-Yosef 2011). As I read the literature, there are two basic approaches. They have in common seeing complex foraging and storage as essential precursors to domestication. But one is a "pull model": the shift to farming results from chasing an apparent opportunity. The alternative is a sophisticated version of forced choice. My money is on this second alternative, in part because we can then connect the emergence of farming with tolerance of inequality and investment in ideology. But first, let's consider some skeptical preliminaries about the pull model, articulated most explicitly by Hayden.[5] For an important methodological claim emerges from these skeptical considerations.

Hayden rejects resource pressure models of the origins of agriculture, because we find these origins in rich environments. So he defends a richness-driven, not pressure-driven, account of the origins of hierarchy, complexity, and domestication. The idea is that inequality and farming arise jointly in environments that are seasonally resource rich. In such environments (*a*) technical innovation opens up the option of storing seasonal surplus; (*b*) sharing and leveling norms erode, as families expect to survive without having to depend on others; and (*c*) storage has the unforeseen side effect of opening up an aggrandizing opportunity. For when possible, families will typically store more than the strict minimum they anticipate needing; they will insure against bad luck and trouble. For the most part, this insurance surplus will not be needed. That gives potential aggrandizers a resource that they can use in pursing influence and power, through being owed favors, and through costly signaling strategies, in particular, by hosting expensive feasts. Once competition for prestige and influence establishes, it drives the establishment of farming, because farming delivers a surplus more predictably and (once intensified) in larger packages.[6] So feasting and food distribution can be used to leverage prestige in the local region, not just in the local community.

There is ethnographic support for a connection among feasting, social stratification, and costly signals. Even so, the model is profoundly puzzling. One problem is empirical. There is evidence that at least in the Levant and surrounding areas, storage began as a communal- rather than a family-level practice (Finlayson et al. 2009; Kuijt and Finlayson 2009; Kuijt 2011). Un-

5. See, e.g., Hayden (2007, 2011) and Hayden and Villeneuvre (2010); for a somewhat different version of the power dynamic, one based on family size, see White (2013).

6. Alternatively, farming might enhance the reliability and predictability of a surplus through a portfolio effect. If a family is producing some foodstuffs, while foraging for others, they have further buffered themselves against risk. Bruce Smith suggests that many cultures domesticated and exploited crops as part of a broad-based resource portfolio, sometimes for thousands of years (Smith 2001).

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less this evidence is misleading, or unless the Levantine example is atypical, early forms of food storage do not create an opportunity for individuals to leverage prestige. But even if the surplus was under individual household control, why should we suppose that an unused surplus buys prestige? If storing more than you expect to need is insurance against exceptional seasonal severity, families in the local communities will tend to have unused buffers at the same time. If these environments really are so rich that sharing norms erode, hardly anyone will need these food bonuses, when they are available. Dried six-month-old fish heads will not buy much support. If, on the other hand, storage itself is risky and prone to failure, then we should expect forager norms of sharing to continue through this technical innovation. Relying on others to contain risk will still be important.

Suppose that this is a mistake, and the aggrandizer currency is indeed valuable. Others need your food, and they cannot expect it as of right, owing to the decay of forager sharing norms. How does that leverage the normative transformation that makes stratified societies possible? Hayden argues that in transegalitarian societies, aggrandizers push through a normative revolution that helps entrench their wealth and interests: for example, (1) hosting of feasts with obligatory reciprocation; (2) the creation of wealth and prestige objects to validate transactions with obligatory returns; (3) the creation of marriage prices so that reproduction requires wealth; (4) the establishment of recognized inheritance so children can inherit the leveraged position of their parents. But how does the fact that the unlucky owe you, and know that they owe you, transmute into a new ideological system that serves elite interests and cuts against the interests of those out of the elite? We have here no explanation of the acquiescence of those outside the elite.

Hayden's explanation depends on the erosion of forager norms, followed by the establishment and motivational power of a new set of norms. There is no doubt that once securely established, norms are motivationally powerful. Once transegalitarian norms are established and supported by the customary and ritual life of the community, it is no surprise that these shape action and make alternatives invisible. It is easy to see that the normative changes that Hayden identifies above would support elites. But what would make them credible? Hayden himself is admirably clearheaded about the appeal to norms in social explanation: such appeals require an explanation of the uptake and stability of norms (see in particular his response in Keen 2006). On Hayden's own views of the instability of normative traditions, the establishment and stability of elite-friendly norms are deeply puzzling. So there is a real tension in Hayden's line of argument. The more successfully he and his coauthors make the case that elites are successfully self-interested, the more strongly commoners should be motivated to resist justifying ideologies and to withhold resource donations. This problem is especially pressing because, as Hayden himself notes, in ranked but pre-state societies, chiefs are

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quite vulnerable to being deposed, and those that demand too much are often replaced (Hayden and Villeneuvre 2010, 126–27).

Hayden's picture of the establishment and stability of rank seems to depend on the power of ideology, since it sees feast holding as the breakthrough, breakout aggrandizer strategy. Aggrandizers use food surpluses to win power and influence (thus fueling a demand for an ever-larger surplus). But what is so great about being invited to a feast? A critical aspect of Hayden's picture of the emergence of inequality is that it takes place in societies with a surplus, where agents are confident of having enough to eat in normal circumstances. So these agents are not starving. For example, in Hayden's case study of Polynesian society, pork-based feasts build prestige. There is no doubting the ethnography: those feasts really do build prestige and influence. But the importance of pork is symbolic and ceremonial. It has no intrinsic material importance in rescuing these agents from starvation or protein deficiency. It is a prestige good—and hence its sociopolitical leverage needs to be explained, not presumed, just as with the rest of a chief's symbolic capital. To borrow some useful conceptual machinery from Dennett (1995), prestige goods are explanatory cranes. Once we have an explanation of their grip on agents' systems of valuation, and of the stability of that grip, we can appeal to prestige goods in explaining social interaction. But without such an explanation, the distorting power of the drive to acquire prestige goods is part of the explanatory target. Individualist models help us see that the establishment of transegalitarian norms is itself one of the puzzling features of the transition to farming. While these norms might help explain the stability of hierarchy in farming societies, they do not help explain the establishment of this new form of social life.

3. The Testart–Watkins Model. An alternative sees farming as developing smoothly from storage-based foraging as individuals adjust adaptively to their slowly changing local circumstances.[7] Testart argues persuasively that storage-dependent foraging preadapts a group for the transition to farming. According to Testart (and collaborators), storage foraging has a set of ecological and technical preconditions:

1. predictable, high-amplitude seasonal variation in resource availability;
2. abundance in the high season;
3. efficient harvesting of the seasonal spike;
4. efficient, low-risk storage.

These conditions set the stage for farming, for the following reasons:

7. See Testart et al. (1982), Watkins (2005, 2010), and also the important contributions of Binford (1980) and Woodburn (1982) to this set of ideas.

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1. Storage-based foragers are already sedentary and already have the food processing and storage technologies on which agriculture depends. Storage foraging, like farming, has deep planning horizons and significant delays between investment and return.
2. To some extent foragers can combine the benefits of storage and the benefits of a large territory with a broad range of resources. They can marry residential settlement with teams targeting specific resources in known but distant locations: resources that can be harvested, processed, and returned to base camp. However, movement costs impose limits to the extent to which groups can combine storage with spatial spread. Storage foragers cannot really manage risk with a broad resource portfolio, and so the shift to farming does not bring new risk management challenges. While domestication and food production were probably for millennia components of a broad-based strategy (Smith 2001; Asouti and Fuller 2013), once the storage of seasonally abundant wild resources became a crucial tool for managing the season of dearth, increasing dependence on agriculture would not seriously elevate their risk exposure. For they already depend on the reliability of their storage techniques.
3. Storage changes forager time budgets: storage foragers face intense demands on their time in the season of abundance as they harvest food and process it for storage. But in the season(s) in which they draw on their stores, their time is available for other uses. This reduces the opportunity costs of preparing, improving, and tending soils, perhaps greatly. That is especially true if some of this work can be off-loaded to those too young, too old, or too infirm to contribute to foraging itself.[8] For the same reason, storage-based foraging reduces the opportunity costs of investment in ideological infrastructure, should that be necessary.

Once storage has become important, there is no economic or technological fitness trench between storage foraging and farming, as there is between mobile, broad-spectrum foraging and farming. Storage foraging and farming are also exposed to common social risks: stored food, whether collected or farmed, is a conflict flash point—a flash point between communities, because stored food in itself is a tempting target for intercommunal raiding, and because the shift to a more sedentary life makes it possible for individuals and families to accumulate more material goods, and these too will be

8. Modeling suggests that family size is quite sensitive to the age at which children become productive: so if children can contribute usefully to food production before they can contribute to foraging for wild resources, this would be important for the demographic consequences of early farming (White 2013).

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valuable to others. But storage is a potential source of internal conflict as well. Boehm's ethnographic survey of mobile forager life documents much grumbling about food and sharing. But while this is common, it is rarely critical (Boehm 2012). Permanently stored food would exacerbate the problem, since the temptation to wheedle, flitch, or bully would be permanent rather than episodic, and because the extended time horizons would make tracking the contribution history of stored food more contentious. Storage foragers needed ways of managing exacerbated internal conflicts over distribution.

So forager storage makes the technical and economic transition between foraging and farming smoother and more incremental. Each step might be the best available, reducing risk or increasing supply by low-cost interventions. Each additional increment in fields, places, or stock is a low-cost outlay, yielding modest return on an existing investment base. But cumulatively, though perhaps over many generations, dependence on produced or managed food increases, and so does the cost of movement. Crucially, the social environment also changes, stressing the mechanisms that support cooperation. These changes prefigure challenges that become more serious, as life becomes more fully sedentary and the farming economy becomes organized around household production and storage. As with the transition from a semisedentary mixed economy to one organized around farming, that may have been a slow process. It is possible that grains were stored communally through the whole PPNA, with household storage not central until the Pre-Pottery Neolithic B (PPNB; Finlayson et al. 2009; Kuijt and Finlayson 2009; Belfer-Cohen and Goring-Morris 2011; Kuijt 2011). However, even if fully household economies only date to the PPNB, this transition imposed severe stress on the forager social contract much earlier.

1. Storage foraging is likely to have demographic consequences. If storage is, as Testart suggests, a response to high seasonal variation in resource availability, it reduces the impact of the season of scarcity on carrying capacity: the lean season is no longer a demographic bottleneck, and the carrying capacity is dependent on the yearly average (Testart et al. 1982). Moreover, sedentary life increases fertility, by easing the mobility/birth spacing trade-off.[9] Mothers (or helpers) no longer have to carry infants to new campsites as the group moves. So there is likely to be local population growth—an effect that intensifies with any shift to domestication, as a larger fraction of total

9. Lawrence Kuznar has pointed out to me that the shift to a sedentary lifestyle also makes available a better supply of weaning foods, allowing a mother to wean earlier and hence pack more children into her fertile years, even at the cost of less nutritious foods and higher infant mortality (personal communication).

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productivity is commandeered for human use. This effect would be strengthened by weeding, thus removing competitors, and by investments in soils that improved their productivity (early irrigation, crop selection, stone clearance, fertilization). So groups are likely to grow, and group size matters. Game theory suggests that the stability of reciprocation-based cooperation is sensitive to group size. As group size goes up, interaction frequencies go down, and the problem of monitoring others becomes increasingly intractable. Size becomes an issue in groups of 50 or so (perhaps less; Bowles and Gintis 2011). Some Epipalaeolithic and early Neolithic settlements seem to exceed this limit, and so there is likely to be pressure on norms of sharing and cooperation (Watkins 2005; Belfer-Cohen and Goring-Morris 2011; Goring-Morris and Belfer-Cohen 2011; Zeder 2011).[10]

2. Private information also erodes the stability of reciprocation-based cooperation, for reputational effects are very important in stabilizing cooperation. It is rational to invest in a good reputation only if an agent's reputation is an accurate reflection of his/her actual behavior. Mixed and early farming economies tend to privatize information. Even mobile forager camps tend to be organized around family-based hearths, and family-based storage and consumption encourage more segmented living. It is true that sedentary life need not involve living in villages composed of single-family dwellings. Ethnography and archaeology reveal plenty of multifamily constructions, and the organization of many PPNA settlements remains enigmatic (Finlayson, Kuijt, and Mithen 2011). Even so, there is probably a rough correlation between the expansion of family-based farming and that of family-based dwelling areas. So farming encourages the growth of private information, further stressing the stability of norms of reciprocation and cooperation.
3. Moreover, storage and farming are more akin to gathering than hunting: both smooth out chance variations in success in daily routines. To the extent that the motivation for cooperative food sharing is to insure against bad luck, that motivation is less strong. Variation in the value of resources acquired over time is likely to reflect differences in skill and commitment. The highly skilled and hardworking will have less reason to share. This effect will be exacerbated if families store their own resources to damp down endemic conflict over food. For then storage is likely to have a corrosive effect on customs of sharing, by

10. Population growth need not result in an increase in size of the modal group. It might, for example, result in small groups being packed more densely in the landscape. But there is no escaping some pressure on the social fabric: intercommunity relations would then be more fraught and difficult.

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> reducing reliance on social capital. A family's fate will depend more on how much they own and less on others' support. In brief, then, the changing nature of the social world and the changing nature of productive activities will both tend to stress the foraging social contract.

So a shift to a mixed forager-farming economy (and still more, a farming economy) tends to erode cooperative practices through its effects on group size, the expansion of private information, and reducing incentives to respect sharing norms.

It also encourages a shift to norms that respect property rights and to formal or informal sanctions for violating them. Storage is a delayed-return economic strategy (Woodburn 1982). As agents shift to mixed economies of collecting and farming, and even more when they become dependent on farming, their lives depend not just on delayed return but on high investment. Farmers invest in their farms and crops: initially, by holding back seed to plant, and then in preparing and improving soils; in tending crops; in investing in tools to grow, harvest, process, and store produce. They invest in a built environment, not just in their lands and crops. These investments in crops and buildings would be profoundly irrational without secure possession of the product. Land could be farmed in common. But as we noted above, differences in skill, commitment, and demand for the product would make such a commons conflict prone. Even with perfect goodwill, it would be difficult to monitor inputs and distribution fairly (Ostrom 1998). And perfect goodwill is not to be found. Unsurprisingly then, it has often been suggested that farming either coevolves with or much strengthens property right norms (Bowles and Choi 2013; Gintis 2013). These function as guarantees of secure possession. Farming thus encourages the privatization of economic life, as investment, production, and storage become more family centered and less community based.

The causal model, then, goes like this. Foraging depletes the resources available to foragers—sometimes imperceptibly, sometimes not. The more skilled and efficient they are, all else equal, the more rapidly they deplete their most favored resources. The result was the "broad spectrum revolution," expanding the forager target range, often accompanied by an expansion of tools and techniques. In favorable environments, that expansion included harvesting and storing seasonally abundant resources. That, in turn, led to a more sedentary life, an expanded population, and selection for still more intense use of available resources (Bellwood and Oxenham 2008).

In regions with potential domesticates, one move in this option space was to enrich the local environment by seeding it with resources,[11] and per-

11. There is clear evidence that Cyprus was seeded with resources by late Epipalaeolithic or early Neolithic foragers.

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haps managing those local patches to increase their value (e.g., using fire to clear weeds before planting). At least initially, these were low-cost measures: the initial labor costs were not intrinsically high, and they were paid when time budgets were not stressed, and perhaps by those not central to the flow of foraged resources. However, an expanded, sedentary population intensively exploiting wild resources in the local region will eventually have a deep ecological footprint, so over time (but probably many generations) the economic center of gravity shifted from opportunistically exploiting wild resources in chance encounters, to intensively targeted and stored wild resources, and thence to managed resources. If farming is ecologically feasible, once foragers abandon movement and invest in place, the slide to farming is both incremental and irresistible. At each stage, agents are making sensible decisions. But the cumulative effect of those sensible decisions leaves agents at the end of the chain with fewer options and a more rigid social environment.

A fitness trap is an innovation that has costs, but which offers a net profit to early adopters. However, once it becomes typical of the population, agents (1) carry the costs but get no benefits, and (2) cannot abandon the innovation without disproportionate penalty. Foot binding and female genital cutting are probably fitness traps: early adopters probably used them as expensive guarantees of sexual fidelity to leverage their family's position on the marriage market. Once these practices became standard in their community, no girl improved her relative position by paying these costs. However, families could not opt out, as they risked dropping out of the marriage market altogether (Sterelny 2007). The Testart–Watkins model suggests that early subsistence farming was a multigeneration fitness trap. Early adopters benefitted from their choice of a mixed strategy, settling in the most productive locations, storing wild harvests but also managing those resources, and reducing risk by expanding their portfolio. But as the practice became universal, and as its effect accumulated over the generations, the combined effects of their investment in place (making moving a choice of last resort), together with the depletion of accessible wild resources, left later generations increasingly dependent on low-rate-of-return, intensively managed resources. The pattern of settlement turnover (as sites establish and disappear) suggests that quite often farming-dependent communities in the early Neolithic were on sinking local optima.

Moreover, once farming establishes, stratification is difficult to resist. Aggrandizers pose a collective action problem, and once family-based farming establishes, it is a very difficult problem to solve. Farming communities are typically larger than egalitarian forager bands, and size alone makes bottom-up processes of persuasion, trust, and coordination more difficult. That difficulty is exacerbated by the shift away from adults engaging in cooperative foraging. Teamwork builds trust and cements affiliation: in family-based

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subsistence farming, trust is no longer a routine by-product of work. These social worlds are less intimate, and not just because they are larger. Furthermore, the ideological climate is less favorable to leveling coalitions. Limited ownership land tenure systems are possible—systems in which a farmer has exclusive right to produce from a block of land, and exclusive right to its products, but with that right becoming void at his/her death. Within such a system, land is not heritable, and so wealth differences in a farming culture will not accumulate across generations. Some traditional leasehold systems work a bit like this, but once property rights in land are recognized, those rights will tend to recognize inheritance. For humans have overlapping rather than discrete generations. Subsistence farmers work the land with their offspring, and so their combined investment across a generation is part of the value of the land, part of its productivity. If property rights exist to make investment in land secure enough to make such investment rational, they will recognize transfer rights to the next generation. Ian Kuijt reads the mortuary rituals of the PPNB in this light. PPNB farmers buried their dead under domestic buildings—in some cases after a time going on to extract and plaster their skulls. He interprets this complex of activities as a material genealogy: bodies and heads are representations of the previous generation. In remembering the dead, the living insist on their role as descendants and inheritors of these ancestors. One could hardly make the claim to be the continuants and heirs of the departed more vividly than by living on top of their bodies and by removing, preparing, and displaying their skulls (in all probability) as props in ritual recitals of genealogy and connection (Kuijt 2008); this interpretation of PPNB ritual is further supported by evidence of a general correlation between investment in mortuary practices and conflicts over land (Kuznar 2003).

If the Testart–Watkins model is right, storage foragers and incipient farmers are less committed to norms of sharing and equality than mobile foragers, and they are less dependent on the good opinion of others. Social capital is still important, but so too is material wealth. These farming groups are transegalitarian. But if the gradients in wealth and power are modest, many of those in the middle will defend property rights. For those norms underwrite secure possession of their own resources, protecting their investment. For this reason, we neither see nor expect to see sharp wealth gradients in small farming cultures. Sharp gradients would make it attractive to join leveling coalitions, and the collective action problem would not yet be intractable.

The Testart–Watkins model fits the archaeology of the Levant quite well. There is evidence of a long Epipalaeolithic record of seed exploitation with settled or seasonally settled life (Watkins 2005; Belfer-Cohen and Goring-Morris 2011; Goring-Morris and Belfer-Cohen 2011). The first signs of retreat from mobility (Ohalo II) are from the Last Glacial Maximum, per-

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haps 12,000 years before the first evidence of domesticated crops and herds (which probably dates to around 12,000–11,000 years BP; Fuller, Willcox, and Allaby 2011, 2012; Willcox 2013). As the model would predict, there does indeed seem to be a long mixed economy; wild and/or partially managed resources were important deep into the PPNB (Conolly et al. 2011; Zeder 2011). Judging from both the number of sites and the size of the largest sites, the late Epipalaeolithic and the early Neolithic was a period of population expansion and increasing network size, with more circulation of exotic materials, but without any marked sign of social inequality (Price and Bar-Yosef 2010). If those signals reflect reality on the ground, social complexity and regional interaction expanded with mixed farmer-forager strategies. These changes preceded the growth of inequality but midwifed its emergence by entrenching property norms and eroding the conditions on which enforced equality depended.

In short, the model is coherent and plausible. It represents Neolithic collector-farmers as rational agents, maximizing expected utility. But it does so with one apparent, important exception. We are still missing an explanation of investment in ideological infrastructure. What was the problem to which Gobekli Tepe was the solution? I shall suggest that here too optimality thinking is insightful, not by showing that heavy investment in ideological infrastructure paid off for early Neolithic agents, but in identifying two potential benefits that would explain the phenomenon we see, and in specifying the empirical footprints we would need to find to confirm their reality. It may be that the increasing institutional and ideological constraints on human action push individualist, optimizing models of Neolithic life beyond the limits of their utility. I have argued that in mass society, we do indeed pass that limit (citation suppressed for blind review). But optimality thinking makes that very question empirically tractable.

4. Tattoos and Temples. Increased investment in ideological infrastructure is in itself perhaps not surprising. This article has identified the escalating pressure on the social contract of the emerging Neolithic world. Compared to the foraging groups from which they came, these villages in embryo were (probably) larger, less equal, less intimate, and with the individuals in them depending more on physical capital and less on social capital. Individuals lived in forced proximity to one another, with their investments in land making it expensive to escape stressed and hostile relationships simply by shifting somewhere else. Yet investment in collective action increased: within the nascent villages of the PPNA and PPNB, domestic structures often shared walls, and these coexisted with apparently communal structures. Moreover, as noted, in the PPNA food storage and processing may well have been collective rather than individual. Later, as the risk of intercommunal conflict became more acute, collective action in

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deterrence and defense became critically important (Bar-Yosef 2010; Ferguson 2013).

Given these stresses, it is widely accepted that Neolithic life depended on new forms of community building and on enhanced investment in ritual activities and their material supports (Watkins 2013). We see this in, for example, the mortuary practices of these peoples. Some of the investment in ideological infrastructure of early Neolithic communities was probably an inescapable investment in such practices. These bonded and stabilized the local communities in which these agents lived, managing conflict and making collective action possible (though we still lack an explicit model of how ritual practices and ritual structures managed conflict and scaffolded community action). But not every case fits this pattern. In particular, the standout example of early ideological infrastructure, Gobekli Tepe, does not. For it represents a scale of investment beyond the resources of any single village. The monoliths themselves are multiton objects, and these had to be extracted, shaped, carved, moved, and placed. To site these monoliths, the masons of Gobekli Tepe had to move upward of 1,500 cubic meters of debris, without animal power and with no metaled tools. Moreover, the archaeology of these enclosures suggests that their construction took place as a single continuous process (Schmidt 2010, 2012). These structures were not built by a few dedicated individuals on an installment plan, over years or generations. They were made by a significant labor force with logistical support. The challenge, then, goes beyond identifying a problem to which monument building is a solution. It is necessary to show that the solution warrants its costs,[12] as well as to show that the supposed solution does not generate its own collective action and defection problem.

Given its costs, Gobekli Tepe was a regional rather than a local investment. Monumental structures are not unknown in the Neolithic (Stonehenge being the most famous example), and the natural suggestion is that these monuments are signals intended to intimidate potential enemies (and to impress potential allies). The idea draws on well-developed ideas from evolutionary biology. In a competitive world without congruent fitness interests, a signal can still be credible when its cost ensures its honesty. The signal imposes a handicap on the sender that only the honest can afford. For example, only genuinely fit and healthy males can afford the elaborate, risky, or exhausting displays that signal high quality to female observers (Zahavi and Zahavi 1997; Maynard Smith and Harper 2003; Searcy and Nowicki 2005). Likewise, only a cohesive, cooperative, and well-resourced commonwealth can afford the expense of a massive monument, and so it is

12. See Drennan, Peterson, and Fox (2010) for methods of estimating the expense (in person-years of work) of ideological infrastructure and estimating a "tax rate"—the annual proportion of local productivity the infrastructure cost.

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a credible signal of power to friend and foe. Monumental structures influence audiences, because only communities that are cohesive and wealthy can build them. The community has a collective payoff through deterrence, and individuals within a signaling community had reputational incentives to participate, since it would be difficult to free ride without detection.

However, while later monuments may well be costly and hence credible signals of power, this picture does not fit Gobekli Tepe. In the early PPNA of northern Levant, there is no real signal of a strife-torn, highly competitive, dangerous intercommunal environment (in contrast, say, to some places in Peru; Vega 2009). There is little skeletal evidence of frequent violent death, or of fortifications, or of settlements located for easy defense rather than easy access to resources, or of specialist weapons technology (Ferguson 2013). No doubt there was aggressive jostling for resources. But the archaeological record does not indicate that intercommunal competition was a dominating feature of the social landscape—that the threat was so serious that it warranted extraordinary displays to deter aggression. Moreover, Gobekli Tepe seems to be alone in the region: no other federation of villages is signaling back; nor does it seem to be the product of an escalation process: there is no sign of older displays of somewhat lower amplitude, no sign of a monument-building arms race. So a community-to-community costly signaling hypothesis depends on finding evidence of serious conflicts between groups, or at least of the ongoing threat of conflict. To date, no convincing evidence of that kind is to hand.

There is a second form of expensive signaling: commitment signaling. Commitment signals are investments that buy trust: they buy trust because the investment is lost if trust is broken (Sterelny 2012; Fessler and Quintelier 2013). Aryan Brotherhood tattoos are expensive commitment devices, because they are essentially impossible to remove. They permanently mark an individual to the gang's many enemies.[13] Once tattooed, you are the target of those enemies whether you retain the gang's support or not. The gang knows this; they trust their new recruit because he is doomed if he betrays them. Commitment signals thus differ from handicap signals because the costs are investments—entry fees—rather than reliable signs of an otherwise hidden quality.[14] A handicap signal can be sent only by the highest-quality agents in a group, whereas it can be in the interests of everyone to

13. For one example of the extraordinary difficulty and pain one person went through to have such tattoos removed, see http://www.smh.com.au/world/pit-bull-of-skinheads-endures-agony-to-remove-tattoos-and-start-a-new-life-20111102-1mug6.html.

14. Gang tattoos thus differ from the scars of old knife fights. Such scars show an otherwise unobservable history of combat survived and hence are hard-to-fake cues of a hidden quality (see Gambetta 2009).

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buy trust through commitment investments. It can be in everyone's interest to join a Friendly Society and to remain a member in good standing.

Importantly, commitment from commitment investment is not dependent on human susceptibility to the fallacy of sunk costs. If the net payoff of trust breaking is greater than the cumulative profit of remaining a member of the cooperating community, then the rational agent will break commitment and sacrifice the investment. But until the invention of money, or of other social institutions that enable an agent to acquire a large resource package through a single transaction and have that ownership generally acknowledged, material resources probably ebbed and flowed in small increments.[15] So the accumulated benefits of a good reputation would rarely be outweighed by a single defecting opportunity, and this fact was common knowledge. In the period before money, and before groups accumulated large stores of exotic material goods (making raiding a serious temptation), the same was probably true of intercommunal relations as well. Perhaps the ritual investments of Gobekli Tepe were commitment signals. Local communities (or perhaps other groups: guilds, kin groups, moieties) paid entry fees to become trusted members of a regional interaction zone, both through the material investment in construction and by investing time and effort, showing their adherence to the normative-ideological framework that these structures express. The investment in ideology brings material rewards, through recognition as part of an in-group.

On this model, monumental investment was a response to an expanded interaction zone. Contributing to the activities of Gobekli Tepe (and other early monumental activities) was an investment that bought a community trust—a good reputation in the regional network. What might this buy? The obvious possibility is access to a trading network. As Paul Seabright points out, trade depends on trust (Seabright 2010). However, while Trevor Watkins has argued that there is good evidence of a PPNA interaction zone (Watkins 2008), he does not think that there is much evidence for a flow of material goods. There is some flow of obsidian, but the quantities are significant only within about 200 kilometers of its sources. He thinks that the evidence is much stronger for a flow of information and technique: he documents regional similarities in symbolism, in artifact fashions (as in the design of projectile points), in material symbols, in mortuary practices, and to some extent in architectural style.

Suppose that Watkins is right, and the limited local surplus and high transport costs (for there are as yet no pack animals) militated against large-scale material trade. Then the payoff from a trusted role in the regional net-

15. The same was probably not true of sexual politics, and so sex was rarely an arena of trust and cooperation.

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work must be from local alliances between villages as part of a risk reduction strategy, and through human capital exchange, capital exchange valuable enough to motivate significant investment in building a local community's reputation, to buy entry into the regional system. Is that likely? In historical times, slaves have been extremely valuable commodities, and they can transport themselves. But we see no evidence of the social inequality that would make plausible an extensive flow of human capital in this form. An alternative is to suggest traveling specialists (like shearers in twentieth-century Australasia): stone masons, flint or obsidian specialists, troubadours and entertainers, healers (whether their powers were real or imagined). This possibility is testable: we should be able to tell whether the material culture of small communities displayed the signs of expertise, of specialized skills, of heterogeneity that could not be supported in a closed village-scale community.

In principle, then, there are human capital flows that might make being part of a regional system genuinely valuable, and hence make an entry price worth paying. If the ticket is worth buying for a community, individuals within communities rationally contribute, given the near certainty that defection would be recognized and sanctioned. The two individualist models make quite different predictions. On the costly signal model, we should find evidence of conflict and competition; if these are the costs of buying a seat at the regional High Table, the scale of the investment should covary with the extent, density, and flow of valued goods and skills through the regional network, rather than with evidence of conflict between the nodes in this network. However, the commitment-signal model is more difficult to test. The costly signaling model relies on the value of deterrence and hence the threat of conflict. Conflict leaves a detectable signature (fortifications, site choice). In contrast, the archaeological signal of material trade can be hard to see, as some potentially important trade goods are perishables (e.g., textiles, or skins). Human capital flows require us to identify skills with regional rather than local bases, showing that the extent of specialization and division of labor exceeds that of a single village economy.

In sum, I suggest that this article vindicates human behavioral ecology as a heuristic tool: it reveals prima facie puzzling forms of behavior, and it identifies potential costs, benefits, and constraints on choice. In discussing the origins of agriculture, the shift to food production emerges as an informed and locally rational outgrowth of existing storage practices. Inequality emerges out of locally rational practices that protect agents' investments in place and land, and out of increasingly difficult coordination problems. Individualist analysis reveals threats to cooperation and collective action implicit in the new demographic and economic conditions of the beginning Neolithic. While we have no well-confirmed model of the expansion of investment in ideological structures, the framework allows us to identify po-

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tential benefits of this investment, and hence tells us what to look for in the empirical record.

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