A dynamic systems approach to technological change: application to the emergence of the potter’s wheel in South Levant

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The dynamic systems framework may be considered an alternative to traditional approaches that study technological change. The benefits of this framework are simultaneously methodological and metaphorical. Methodologically, the framework provides a coherent analytic process for studying empirical data to explain the complexity of technological change. Metaphorically, the framework appeals to local-scale “interactive mechanisms” to account for the origins of change. Applicability of the dynamic systems framework for studying technological change is illustrated with an archaeological case study: the emergence of the potter’s wheel in southern Levant during the 4th millennium BC.

KEY WORDS: dynamic systems; technology; innovation; potter’s wheel.

INTRODUCTION

Change, as a multiphenomenal dynamic, is a major issue in the study of material culture and technology. As clearly demonstrated by a broad spectrum of studies cross-cutting different but related disciplines (cultural anthropology, sociology, ethnosciences, archaeology, history), these myriad phenomena result from complex interactions between technical systems and social contexts (e.g., Akrich, 1994; Cresswell, 1996; Dobres and Hoffman, 1994, 1999; Gosselain, 2000; Latour and Lemonnier, 1994; Lechtman, 1977; Lechtman and Steinberg, 1979; Lemonnier, 1986, 1992, 1993; Leroi-Gourhan, 1973; Pfaffenberger, 1992). They can be analyzed using different theoretical frameworks such as structuralism,
situational and distributed cognition, design theory, practice theory, and functionalism, to name but a few. As well, various methodologies can be employed, whose primary objective is to explain variable processes of change as culturally constructed and socially constituted (Schiffer, 2001, p. 3). To disentangle the deeply interwoven technical and cultural factors involved requires comprehending the various mechanisms at play. For this purpose, activities involved in artifact “life histories” are often studied according to the analytic known as chaîne opératoire\(^3\) (e.g., Balfet, 1991; Cresswell, 1983; Lemonnier, 1983; Pelegrin et al., 1988; in English, see Dobres, 2000, pp. 167–287) or its near-kin, behavioral chain analysis (Schiffer, 1975). In this paper, I argue that comprehending technological change and empirically verifying one’s interpretations requires consideration of the chaîne opératoire of an artifact class in terms of a dynamic process that is distinguished from the sociocultural context within which that life history took place. The theoretical framework considered here is known as “dynamic systems.” A dynamic systems framework was developed initially to explain change in biological and physical systems—complex, open, and nonlinear systems that respond to precisely specified constraints (Aslin, 1993; Butterworth, 1993). Recently, a dynamic systems framework has been employed in experimental psychology as an alternative approach to the traditional neuro-maturationist and cognitive approaches for understanding motor, cognitive as well as perceptual development (Smith and Thelen, 1993; Thelen and Smith, 1994). Applied to the study of technological change, the benefits of using a dynamic systems framework are simultaneously methodological and metaphorical. Methodologically, a dynamic systems framework provides a coherent analytic process for studying empirical data to explain the complexity of technological systems and technological change. Metaphorically, the framework appeals to local-scale “interactive mechanisms” to explain the origins of change.

To illustrate the efficacy of a dynamic systems framework for studying technological change, the second part of this essay provides an archaeological case study concerning the emergence of the potter’s wheel in southern Levant. This technique, which originated in the Old World as early as the beginning of the 4th millennium BC, raises important questions about the factors responsible for this major technological innovation. The traditional hypothesis accounting for the emergence of the potter’s wheel implicitly ties its invention as a tool to the wheel-throwing technique, and considers efficiency (specifically the reduction of time required to produce a vessel) as the driving force for the adoption of the wheel

\(^3\)In France, this concept finds its roots as early as the first part of the twentieth century, through scholars, such as Mauss (1967), who underlined the necessity of studying “les différents moments de la fabrication depuis le matériau grossier jusqu’à l’objet fini”; Maget (1962), who insisted on the necessity of studying the activities involved in the “chaînes de fabrication”; and Leroi-Gourhan (1964, p. 164), who clearly specified that “la technique est à la fois geste et outil, organisés en chaîne par une véritable syntaxe qui donne aux séries opératoires à la fois leur fixité et leur souplesse. La syntaxe opératoire est proposée par la mémoire et naît entre le cerveau et le milieu matériel.”
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(Foster, 1959). However, recent studies may have refuted this hypothesis (Courty and Roux, 1995; Roux and Courty, 1998). Empirical evidence now suggests that Middle Eastern devices of the 4th–3rd millennium BC were used to fashion pots not through wheel throwing but through wheel shaping, a time-consuming technique. The wheel-shaping technique of pottery manufacture at this time consisted of thinning and/or shaping coiled roughouts on the wheel, rather than throwing then shaping an unformed lump of clay. In the southern Levant, the wheel-shaping technique appeared during a time of profound sociopolitical change (Levy, 1998; Levy and Holl, 1988). Interpreted within the dynamic systems framework, these archaeological data suggest that the wheel-shaping technique (in spite of its time expenditure) was invented and adopted as a response to demand for new ritual vessels.

APPROACHES TO TECHNOLOGICAL CHANGE

To study and make sense of technological change, many explanatory models developed in philosophy, sociocultural anthropology, sociology, economics, and especially archaeology depend on a duality that separates technology and society (Dobres, 2000, pp. 14–65). Then, depending on whether this duality is conceptualized as an explanatory paradigm or a method of investigation, the models propose either a linear or nonlinear account of technological evolution (Akrich, 1994).

Where the technology–society duality is understood as an explanatory paradigm, external need is seen as the driving force of technological evolution, whereas specific modalities of change are determined by rules internal to the techniques themselves (Gille, 1978; Simondon, 1958). There is, on the one hand, the technological system, with its internal functioning as well as an evolutionary potential. This latent potential for change is related to the many possible combinations between mostly preexisting elements. On the other hand, external to the technological system are social, economic, and political systems that act as triggers. Causal social factors of “need” explain the emergence of new technological systems, whereas in large measure techniques are self-contained and determine their own development. The origins of innovation are therefore found in those technological systems that cannot, within themselves, respond to new needs, whereas particular forms of innovation depend on internal rules of evolution.

As an explanatory paradigm, other studies argue for interactions between technology and society and explain technological change as a result of these interactions. To be sure, technology and society are intrinsically linked, continuously reshaping themselves and each other in a never-ending feedback loop (e.g., Leroi-Gourhan, 1973; Marx, 1967; Mumford, 1967). Unlike the above scenario of external causality, however, in this case there are no triggering mechanisms. Rather, there are a series of mutually reinforcing interactions and retroactions.
between macrotechnological and macrosociological entities (Akrich, 1994, p. 117). Whatever the specific factors invoked to explain the innovative results of these interactions (e.g., some external pressure, plays for power, the mechanization of productive activities), they evolve in a linear fashion.

In contrast, where the duality of technology and society is understood as a heuristic method of study, research into the design process endeavors to understand the specific factors involved and is achieved by scrutinizing the artifact’s chaîne opératoire. Different analytic frameworks are employed to identify the series of activities pursued during different stages of manufacture and use (e.g., Geneste, 1988; Hayden et al., 1996; Pelegrin et al., 1988; Perlès, 1992). With reference to both the physical artifact and environmental constraints, these activities are then analyzed in terms of the technician’s intentions. Such studies reveal the specific technical choices pursued, and thus the social, physical, functional, and somatological (Bleed, 2001) factors that may have played a role in instigating technological change. More particularly, a behavioral approach to studying processes of artifact design (e.g., Schiffer and Skibo, 1997; Skibo and Schiffer, 2001) argues that an artifact’s life history is determined by technical choices affecting the item’s formal properties. Technical choices are influenced by any number of external factors—behavioral, social, and environmental—that impinge on the activities of an artifact’s behavioral chain and are embodied in each activity’s specific component” (Schiffer and Skibo, 1997, p. 34). This variability in artifact design results from compromises between formal properties and “ideal” performance characteristics, which themselves vary among producers and users. Such necessary compromises depend not only on feedback between the producer and the consumer, but also on the experiences and context of the producer’s apprenticeship (Schiffer and Skibo, 1997, p. 33). Compromises also result from navigating a matrix of law-like correlates concerning the effects of formal properties on performance characteristics. According to the behavioral approach, then, study of the relationship between performance characteristics and formal properties may explain a craftsman’s behavior throughout the artifact’s life history. Moreover, craftspeople are supposed to optimize their strategies, or routines, for negotiating the opportunities and constraints such law-like correlates impose. Ultimately, technological change depends on compromises: those resulting from interactions between the technological and social spheres (either of which can be causal), as well as compromises involving formal properties (which are delimited and weighted according to particular performance characteristics).

To abolish the conceptual dualism of technology–society as two distinct attractors (Latour and Lemonnier, 1994, p. 21), and simultaneously move beyond linear models of the evolution of technological change, a new trend in sociocultural anthropology and sociology sees material culture as simultaneously formative and constitutive of both culture and society (e.g., Dobres, 2000). Technology and society are considered as integral, indeed inseparable, parts of a complex whole,
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and change results from processes deeply embedded in their sociocultural matrix. Fundamental to this constitutive (rather than dualistic) perspective is the notion of cultural representation. Particular sorts of interactions “between” the technological and social spheres take shape according to existing cultural forms of representation, and these representations ultimately determine technological choice (Latour and Lemonnier, 1994; Lemonnier, 1989, 1993; Pfaffenberger, 1992). Thus technological features are either retained or subject to alteration depending on the previously established integration of their symbolic, social, and/or functional significance within even wider networks of meaning. The integration of new technological practices or forms depends on the degree of coherence possible between existing cultural perceptions of material elements and modifications to the manufacture and use process. These cultural perceptions of the technological arena, as well as particular networks of technical practice, are supposed to be structured by a “worldview.”

One methodological strategy for identifying this worldview is to separate what pertains to the “real world” of technical constraints from what does not. What is not subject to such technical constraints is then explained by the cultural logic underlying both technological practice and social life (e.g., Mahias, 1993; Miller, 1985). Two methodological problems follow from this strategy (Akrich, 1994; Cresswell, 1996). First, varying as they do across space and time it is very difficult to explain how different forms of cultural logic can underlie the production of similar tool forms (e.g., stone adzes) or techniques (e.g., stone polishing), and vice versa. For example, as Lemonnier admits, “social logic and meaning permeate all techniques, but with apparently the possibility of opposite outcomes, sometimes immobility, sometimes change” (Lemonnier, 1993, p. 22). Second, it is difficult to refute through empirical means explanations proposed for particular technological choices. Indeed, researchers who study technological change using a constitutive and structural approach (e.g., Hodder, 1982; Lechtman, 1999) seem to believe that a single demonstration of the structural logic underlying some technological choice is sufficient to conclude the existence of an underlying structure. On the contrary, failure to demonstrate that a single worldview permeates numerous technological choices is simply not informative because those choices, and that worldview, may only reflect the researcher’s failure to demonstrate that “something is also at work in the social production of techniques that makes them conform to some necessary physical principles of action on the material world” (Lemonnier, 1993, p. 24). This approach, obviously rooted in structuralism, thus pursues a problematic scientific position by taking into account only certain kinds of evidence while ignoring others. As an example, the different technical solutions met in the history of aviation may be thus interpreted in terms of arbitrary choices when decisive technical, economic, and environmental parameters are ignored (Lemonnier, 1996; Quilici-Pacaud, 1993).

Another and surely better way to appreciate the complexity of technological practices and choice, while also developing more rigorous methodologies to
undertake such research, derives from an “ecological” or “perception-action” perspective, as found in studies of technical skill (e.g., Bril et al., 1998, 2000; Ingold, 2001; Roux and Corbetta, 1989; Tanon, 1989). In this perspective, skills emerge from the dynamic interaction that occurs between the task, the environment, and the subject (Newell, 1986; Suchman, 1987). Apprenticeship is not reduced to simple cause-and-effect relationships between artifact and subject, between subject and subject (master vs. apprentice), or between artifact and artifact. Nor does the acquisition of a new skill, technique, or tool require its previous representation within the underlying logic of the cultural system. “Perception-action” and related network perspectives have much in common with the dynamic systems framework described below.

THE THEORY OF DYNAMIC SYSTEMS AND ITS APPLICATION TO TECHNOLOGY

In general, the theory of dynamic systems is concerned with the study of change (Prigogine and Stengers, 1984), and understanding the processes underlying the transformation of systems is the main objective. Briefly, according to the theory of dynamic systems, changes that occur within any constantly evolving system are influenced by a multitude of factors that interact in complex ways. The complexity of interacting factors is due to the fact that systems are themselves composed of numerous different components that continuously interact amongst themselves and with the environment in extremely variable ways. Like general systems theory (of the 1970s and 1980s), primacy is given to interactions between the components of the system, and the ability of the system to self-equilibrate. However, unlike general systems theory, change is viewed as a dynamic assembly rather than a hierarchy of structures. It is impossible to discern any hierarchy or a privileged status for any of the components involved. Moreover, change is seen as a process of selection rather than construction. In other words, change is not seen as a process of adaptation and equilibrium inherent in homeostatic system, but as an emergent property of complex patterns of interaction assembled in real time. It follows that for dynamic systems to change, it is not necessary to appeal to any preexisting cultural representations.

To be clear, however, the dynamic systems framework discussed next differs radically from similar-sounding approaches which, to explain societal change in the past, utilize some dynamic theory of nonlinear systems. Such studies have proposed theories and models, but do not explain the observed reality of particular historical instances. Models have thus been designed for understanding the oppida⁴ from La Tène (van der Leeuw and McGlade, 1997). This form of incipient urbanization is understood as a prestige goods economy. The authors conclude that “From a

⁴Latin word for designating fortified towns.
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social perspective, chaotic evolution and strange attractors allow us to see the evolution of structures as broadly cumulative and stable at a macroscopic level of description, but characterized by erratic and idiosyncratic properties at lower, more local levels” and that one of the fundamental lessons of chaos is “the impossibility of reductionist explanation for natural phenomena” (van der Leeuw and McGlade, 1997, p. 359).

Save that these results are quite obvious and that modelling is per se reductionist, let us underline the fact that the authors recognize that,

...none of these ideas has the pretence to represent “reality.” Even if such a representation were theoretically possible (and we do not think so), it is much too early to adopt one. For the moment we are in that delightful phasing of “playing with hypotheses,” and have tried to show that they are different kinds of games out there, which are fun because they bring us some glimpses of insight which add to our understanding. (van der Leeuw and McGlade, 1997, p. 367)

As Francfort (1999, p. 9) puts it, the problem is that we are then in a situation where “the model does not rely on the acquisition of [observable] facts, the acquisition of archaeological data, but relies on a theory, a socio-x model.”

There then follow serious problems of validation which “can never be based on a logico-mathematical model, nor depend on this model, [validation] but is bound to the theory of the socio-x model” (Francfort, 1999).

Scientific metaphor and the transfer of concepts can help archaeologists move toward interpretation, but they must not prevent from respecting the exigencies of internal consistency and empirical validation (Francfort, 1997). The dynamic systems framework here presented elaborates no theoretical model of technological change. On the contrary, empirical analysis is privileged and subsequent hypotheses to account for the process of technological change and dynamics of artifact population are then tested against archaeological data.

The theory of dynamic systems is most applicable to systems that are complex, nonlinear, and open, and that respond to precisely specified constraints. An extremely important question one must pose, then, is whether technology meets these criteria and is, therefore, an appropriate domain to be investigated using this framework.

“Technological Facts”: Complex, Nonlinear, and Open Systems

As stressed previously, technological practices are deeply embedded within their social and technological matrix. Mauss’ term, “technological fact,” connotes this embeddedness; the term was employed by many (e.g., Haudricourt, 1987;
Sigaut, 1994) before being abandoned in favor of “cultural choice” (Lemonnier, 1993; Lévi-Strauss, 1973). Indeed, social anthropologists feel that “technological fact” is a reductionist term, because it highlights a priori the duality of technology and society, thus confusing how the technological system and society are so tightly interwoven. The expression “cultural choice,” however, is more appropriate for describing the very cultural, and in this regard, arbitrary character of the technological fact. The expression “cultural choice” is not preferred here, because it presupposes that social groups have made some choice by selecting one technical solution or practice from among several known possibilities. However, technical solutions chosen by the social group are rarely, if ever in preindustrial societies, selected from a viable list of known solutions, just because technology is embedded in society and that, all other things being equal, craftspeople do not face therefore true technical alternatives. Moreover, the term “choice” precludes research into the existence of possible laws of technological evolution which were not open to choice, as examined by Simondon (1958), Gille (1978), Leroi-Gourhan (1973), and in some respects by Schiffer and Skibo (1997).

In the remainder of this discussion, I employ the anthropological term “technological fact,” defining it as a complex system characterized by interactions among numerous nonhierarchically ordered components that operate in and across technological and the social domains. The metaphor of “seamless web” (Akrich, 1994; Hughes, 1979) evokes the nature of these complex interactions especially well. The complexity of these interactions is due to the fact that the components involved are heterogeneous; they belong to distinct domains (the social and the technological), yet form a single whole—the technological fact—which is destined to change over time.

Defining the technological fact as a complex system, however, does not make it a substitute it for the term “technological system,” which is defined by French cultural technologists as an ensemble of techniques, a network of chaînes opératoires, practiced by a group and forming an organized whole (Cresswell, 1996; Gille, 1978). A technological system has more in keeping with what economists call a global technosystem (e.g., an “agro-system”; Matarasso and Roux, 2000).

In the dynamic systems framework, the nonlinearity of a complex system signals a qualitative change in function and results from some modification of the interactions ongoing between different components, factors, and elements. Technological facts are, per se, nonlinear in the sense that changes observed over the course of the history of techniques are qualitative, not quantitative; changes are characterized by new properties. Thus Cresswell’s view (Cresswell, 1996, p. 21) that “techniques are linear in the sense that they necessitate a certain order of development”7 does not apply to the concept of technological facts under discussion. Linearity does not bear on the order of development, but rather on its nature—qualitative or quantitative.

7“les techniques sont linéaires en ce sens qu’elles nécessitent un certain ordre de développement.”
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One final point: in keeping with the conditions of complexity and nonlinearity, open systems are those which emphasize the constant exposure of the system to change from within. In this regard, technological facts are open systems because they result from continual interactions and exchanges between the technological and social domains. In turn, the technological and social domains are themselves transformed through such interactions (see, e.g., the sociological studies which examine the consequences of technical innovation on social structure; e.g., Ogburn, 1957, cited in Akrich, 1994). Furthermore, because the technological fact is an open system it is impossible to predict the characteristics of a new technique based on preexisting meanings and social logic—and vice versa (Lemonnier, 1993, p. 24).

There are three components which together form a technological fact and which are themselves subject to continual exchange:

1. The technical task, here defined in terms of chaînes opératoires and skills.
2. The environment, which serves as the source for materials used in some technical task.
3. The subject, who carries out the technical task and whose intention(s) are rooted in the group’s sociocultural representations.

The properties of each component respond to constraints operating in one of two ways: either (1) within the properties themselves; or (2) at the macrolevel of the technical task, the environment, or the subject, which together constitute the technological fact. For the technical task and the environment, constraints are cross-cultural and can be analyzed independent of the sociocultural context in which they take place. In archaeology, these cross-cultural constraints can be specified through actualistic (replicative) study (Schiffer and Skibo, 1987).

The Technical Task

As previously mentioned, the technical task can be described independent of the cultural context within which it takes place. It is a subsystem possessing its own dynamics, but whose actualization is dependent on the dynamics of the technological fact. In archaeology, description of a technical task is accomplished with reference to data derived from actualistic studies and/or ethnoarchaeology.

A technical task refers to the techniques that enable the transformation of raw materials into cultural objects, and can be identified by analyzing an object’s chaîne opératoire in concert with the skills of the technician.

(A) The chaîne opératoire. Analogous to economic networks, the chaîne opératoire may be defined as the suite of elementary technical operations that lead to the production of particular types of objects (e.g., Balfet, 1991; Cresswell, 1996; Dobres, 2000; Pelegrin et al., 1988; Roux and Matarasso, 1999; see also the definition of a behavioral chain in Schiffer and Skibo, 1997). A chaîne opératoire is described in terms of (1) techniques (physical modalities by which raw material is
acquired and transformed), (2) methods (the particular sequence followed), and (3) tools. The tools or instruments employed in some chaîne opératoire are described according to the physical features of the technical action.

Techniques, methods, and tools can be characterized in terms of efficiency as well as spatial, temporal, and evolutionary properties. The efficiency of a technical task can be measured using different indexes (such as number of objects produced/duration of work), and can be analyzed independent of the subject’s intention(s). For example, while one technique can be faster than another, its use may not be due to someone’s desire to save time but because it is more appropriate to other properties of the task (Rice, 1996). The spatial and temporal properties of a technical task relate mainly to the organization of the task and can conform to cross-cultural (law-like) constraints. Spatial properties account for the organization of the different stages of the chaîne opératoire at intra- and intersite levels, whereas temporal properties account for the organization of these stages through time. For example, in ceramic technology temporal constraints can relate to drying time, which in turn constrains both the organization of the task and the number of pieces produced daily. Evolutionary properties of techniques, methods, and tools concern the potential for internal change in the technical task. Importantly, this potential for internal change requires no social motivation. An internal “motor” for change is what Leroi-Gourhan (1973) meant by tendance (tendency). This internal tendance operates in the sense of some development (or change) that spares human energy (after Cresswell, 1996, p. 21). In other words, techniques, methods, and tools may have their own rules of internal evolution that bear on the potential reorganization of structural elements (Simondon, 1958).

(B) Skills. In an efficient manner, skills put techniques, methods, and tools into action and are acquired by apprenticeship (Bril et al., 1996). Skills are at the heart of the mechanisms that underlie changes in technical tasks, because a new technical task necessarily requires new skills. The skills that enable a technical innovation can be characterized as either continuous or discontinuous, according to whether the individual had to acquire new capabilities or could build on pre-existing ones. The necessity of characterizing technical gestures in sequence, to describe fully a technique, has been strongly underlined by Mauss (1935) and Leroi-Gourhan (1964). In particular, Haudricourt (1987) has shown that the evolution of techniques could depend more on gestures than on the technical methods of production.

In archaeology, although technical gestures may be difficult to reconstruct, skills may be characterized through actualistic studies using methodologies developed by the science of ergonomics (Roux, 1990, 1997). Skills can be characterized with respect to capabilities acquired during different stages of apprenticeship and

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8 A same technical action can be achieved by different technical gestures. For example, a bow drill can be maintained either by the palm of the hand (cf. India) or by the teeth (cf. Eskimos). The bow drill itself gives no indication of these different gestures.
to biomechanical constraints (Bril et al., 2000; Roux and Corbetta, 1989). They can also be characterized in relation to other techniques: for subjects practicing technique \(x\), what problems, in terms of skill, arise by the practice of technique \(y\) (Gelbert, 2000)?

Studies of the skills underlying the execution of a technical task fit comfortably in the realm of the cognitive sciences, which provide several useful theoretical frameworks. From a dynamic systems framework, a combination of ecological and situational cognition theory allows the study of skills in all their complexity, analyzing them in terms of the mastery of dynamic interactions existing between the subject and their environment during some activity (see, e.g., Bril et al., 1998, 2000; Suchman, 1987).

**The Environment**

The environment is characterized by the raw materials available across a landscape and its properties. In ceramic technology, for example, environmental analysis identifies locales bearing clay deposits, then characterizes the properties of different clay and temper resources in terms of (1) their modes of access and (2) quality. **Modes of access** are determined by factors of distance and facility of extraction, whereas raw material **quality** is determined according to (1) the resources available, (2) techniques used to produce a ceramic object, and (3) the finished product, whose intended function(s) can imply strong constraints.

**The Subject**

An object is produced by a subject whose intention(s), as well as the cultural representation of their work, necessarily take place within a sociocultural context. The subject’s intention(s) provide a strong social significance to the object being made and used. In archaeology, some part of the subject’s intention(s) can be known by determining the function of the object [e.g., the function(s) of ceramic pots]. Such functions can be traced to some demand originating within the sociocultural community. The subject’s intention(s), which thus depend on social context and demand, bear their own constraints while also being constrained by properties of the technical task and the environment.

**The Technological Fact: An Emergent Process**

Central to any dynamic systems approach is the hypothesis that new systems emerge from a complex set of interactions among internal components and self-organize over time (Smith and Thelen, 1993; Thelen and Smith, 1994; see also
ecological perception theory, Gibson, 1979). From this perspective, technological change is conceptualized as the result of a dynamic and complex process emerging from interactions among properties of the constituting components. In other words, technological change achieved in the task–environment–subject nexus comes about through the dynamic interplay of all the components involved. Importantly, it is not the result of compromise between factors such as environmental or culture, nor is it simply an innate expression of evolution. Technological change is the patterned result of complex interactions within the system itself. And precisely because these patterns of interaction are complex, it is impossible to define a hierarchical order or assign a particular (determinant) status to any specific component of the system. On this point, principles of dynamic systems theory converge with those sociological principles according to which humans and nonhumans have to be studied as “equal partners” to better interrogate the role of objects in social interactions as well as the recursive and dynamic construction of society and technology (Latour and Lemonnier, 1994). However, principles of dynamic system theory diverge from the tenets of structuralism, according to which some preexisting cultural representation (e.g., of the technological fact) coherent with the general “worldview” of the group is necessary for its actualization. According to structuralist principles, sociosymbolic representations play a prominent role in the selection of particular behavioral (including technological) choices. To the contrary, in the dynamic systems framework the concept of self-organization means that there is no prerequisite structure underlying the several constituting components of the system; in other words, there is no underlying structure or “worldview” determining the particular form that change will take.

However, this does not mean that technological facts are only determined by constraints operating within the system. It is still left to the subject and the group to choose among various characteristics of the system’s components, factors, and elements. This level of choice comes from in some way playing with the set of constraints that become the newly emerging properties of the system (Newell, 1986). From this perspective, then, internal evolution and the related process of technical invention can be viewed as emergent properties, or attractors, of the technological fact.

Connecting Real Time and Historical Time

From a methodological point of view, the dynamic systems framework connects real time and the *longue durée* of developmental time by recognizing that constraints of the most elementary components of a system can, over time, affect its global structure or form (Aslin, 1993). In the study of technology, this should enable us to deal simultaneously with invention and innovation. *Invention* is what happens locally, at the scale of the individual; it affects the evolution of the system when it becomes an *innovation* through its widespread acceptance (van der Leeuw
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and Torrence, 1989). Invention happens at the level of the technical task and results from a complex interaction between a new mode of action on some material (e.g., a new technique, method, or tool) and/or the development of new skills. This interaction expresses individual cognitive activity, whose release can come about in one of two ways: (1) it can be internal to the technical task (e.g., through the technician’s discovery of new technical properties intrinsic to an already known object, or through the transfer of technical properties from one object to the other); or (2) external to the subsystem (e.g., because of a change in the environment and/or the demand). An analysis of innovation and a group’s acceptance of technological change requires analysis of the subject’s intention(s), which are rooted in the sociocultural arena and its collective representations. Indeed, from the point of view of historical time the dynamic process underlying innovation results from variability operating at the scale of the collective, and not from individual inventors. Furthermore, innovation is expressed by the emergence of a new tradition, whose development and acceptance can be slow or rapid according to context. Coupled with the constraints of the environment (which is the context of actualization), it is the temporal course of these two interacting variables—the individual and the collective—which gives the system its faculty to adapt and bring about widespread technological change.

Why Change at Particular Moments in Time?

As to the question of why change happens at specific “moments” in time, the dynamic systems framework suggests the necessity of considering the context into which takes place qualitative change. In terms of technology, this context of change corresponds to the conditions actualizing the change, that is, the context of craft production (in the broadest sense of the term).

Thus, the dynamic systems framework distinguishes clearly and fundamentally between the mechanisms underlying the formation of a technological fact and the conditions within which it is actualized (Fig. 1). Processes underlying the creation of a technological fact pertain to the complex of interactions between sets of components whereas the conditions actualizing it pertain to the context of craft production. Thus, the social domain is no longer analyzed as a global entity whose components and elements interact with the technological domain (as a “seamless web”). Now, the social domain is limited to the sphere of actualization in which is rooted the subject’s intention(s).

By comparing various “actualizing” conditions wherein technological change takes place, one can hope to highlight general rules of technological evolution. Given the fact that context may affect the dynamics of technological change, such rules have to be sought for comparable changes (continuous vs. discontinuous) and whose production context is comparable as well. For example, to investigate some general rule of technological evolution, it would make little sense to compare the
emergence of the pottery wheel (discontinuous development) with the development of the pottery-burnishing technique (continuous development).

**The Necessity of Empirical Data**

The application of a dynamic systems framework to the study of technological facts requires a large empirical database. This is why dynamic systems theory, *per se*, is not discussed here. Rather, it makes better sense to talk in terms of a framework that is, simultaneously, a methodological and a metaphorical tool for describing data and proposing hypotheses. Another goal is to create a vast empirical database to assess interactions between the different components and their resulting dynamics. These tests can bear on past and present technological facts.
AN APPLICATION OF THE DYNAMIC SYSTEMS FRAMEWORK:
THE EVOLUTION OF THE POTTER'S WHEEL

The emergence of the potter’s wheel is a particularly relevant case study for demonstrating the efficacy of the dynamic systems framework for studying technological innovation, given that the wheel’s use of rotary kinetic energy (RKE) corresponds to a highly constrained technological system (a system whose component properties are characterized by strong constraints). Indeed, the practice of the RKE technique implies the mastery of perceptual-motor skills learned over a long period and discontinuous with skills previously developed for fabricating ceramic pots (Roux and Corbetta, 1989). This difference in technical skills may be measured in terms of the duration of apprenticeship. Mastering the wheel-shaping technique (using RKE) requires 10 years of practice, whereas mastering the coiling technique requires only 2 or 3 years. The cross-cultural character of these apprenticeship periods has been determined on the basis of field experiments (including psychological tests), and highlights the observation that potters who practice wheel-shaping techniques elaborated their specific perceptual-motor skills progressively, over time (Roux and Corbetta, 1989).

From an historical perspective, the emergence of the wheel-shaping technique draws attention to the problem of a technological discontinuity and the conditions (or context) of this discontinuity. Indeed, among traditional societies the norm is to reproduce technological practices and through such means maintain a stable technological system. This stability (which should not be confused with homeostasis) can be punctuated by minor modifications (Cavalli-Sforza et al., 1982), but such punctuations need to be distinguished from the major ones—the discontinuities—which signify general technological evolution.

Methodologically, three main stages of investigation characterize an archaeological application of the dynamic systems framework, because ancient technological facts can be analyzed as complex systems. Stage 1 collects the requisite data with which to describe the three components of a technological fact: (1) the technical task, (2) the environment, (3) the subject’s intention. Stage 2 classifies these data using analytic and classificatory procedures perfected in actualistic studies. Stage 3 interprets these data. Interpretation operates on several levels: (1) it permits identification of technical tasks, exploited resources, and the subject’s intention(s); (2) interpretation allows characterization of their various properties; and (3) interpretation sets the stage for proposing hypotheses about the mechanisms at work. On this level, the metaphorical power of the dynamic systems framework can resolve problems raised by the interpretation of empirical observations.

Archaeological Data

During the first half of the 4th millennium BC, a new technomorphological type of ceramic appeared in the southern Levant: V-shaped bowls fashioned
Fig. 2. Abu Hamid V-shaped bowls shaped using rotary kinetic energy (RKE).

on a rotary device (Balfet, 1962; Commenge-Pellerin, 1987, 1990). On southern Levant archaeological sites of the same cultural horizon, these V-shaped bowls (Fig. 2) whose dimensions vary represent 40–60% of all ceramic production (e.g., Commenge-Pellerin, 1987, 1990; Perrot and Ladiray, 1980; Ussishkin, 1980). They appear concomitant with the development of large villages, long-distance exchange networks, evidence of territoriality, specialized burial areas, and ritual places (Levy, 1985; Levy and Holl, 1988; Perrot and Ladiray, 1980). In other words, the emergence of the wheel-shaping technique appears at a time of important structural changes in the fabric of Chalcolithic society. These changes have been interpreted in a number of different ways. According to one hypothesis, they are due to the emergence of a hierarchical “chefferie,” or chiefdom (Levy and Holl, 1988). According to another, these changes do not signify vertical realignment (Gilead, 1988) and the societies in question remain egalitarian.

To understand the dynamics processes at work in the emergence of the wheel-shaping technique, we have begun with a technological analysis of the ceramic material from Abu Hamid, a settlement located in the Middle Valley of Jordan and
occupied from the 6th to the middle of the 4th millennium BC. V-shaped bowls first appear in layers dating to the first half of the 4th millennium BC (Dollfus and Kafafi, 1988).

Emergence of the Wheel-Shaping Technique: Components of this Technological Fact and the Craft Production Context

To understand the dynamics underlying the appearance of the wheel-shaping technique, the technical task, the environment, and the intention(s) of potters need to be identified and described and their properties studied.

The Technical Task

The chaîne opératoire of V-shaped bowls has now been identified on the basis of surface features and microstructural evidence, the diagnostic characteristics of which were established independently, through actualistic and replicative studies (Roux and Courty, 1998). The chaîne opératoire of V-shaped bowls is as follows (Roux and Courty, 1997): (1) the base was fashioned by flattening a small lump of clay; (2) in the shape of a big spiral coil, the base was fixed directly on the wheel or on a support; (3) the body was formed by laying a series of circular coils on top of each other; (4) the base was strengthened by adding one or two coils to the inferior part of the internal walls; (5) the coils were joined by hand pressure; (6) the roughout was then centered, (7) and thinned with RKE using continuous pressure; (8) the vessel was subsequently shaped, also using RKE; (9) the vessel was then removed from the wheel either by cutting under the base with a string or by detaching the coil support from the roughout; (10) the vessel was dried on mats; (11) then, without the help of RKE, the external base was strengthened by applying little coils which were then flattened with a wooden tool; and (12) the final stage was to (again) dry the vessel on mats. Compared with the (older) coil fashioning technique, the novelty of this chaîne opératoire resides not in the shaping method, but in the use of the RKE technique for thinning and shaping operations.

Because the bodies of V-shaped bowls were modified by RKE, it is reasonable to suppose that the rotary device—the wheel—offered a sufficient moment of inertia capable of resisting the friction caused by the finger/hand pressure necessary to thin and shape clay walls. Experiments indicate a speed of ~80 rpm. In contrast, “the speed appropriate to throwing is between 50 and 150 rpm, being inversely proportional to the diameter of the vessel at the point where pressure is applied” (Rye, 1981, p. 74). Given this observation, the relatively small sizes of wheel-shaped vessels cannot be taken as evidence that the device was not rotating fast enough for shaping larger vessels.
Rotational motion was known before the 4th millennium BC. Indeed, attributes indicative of rotational movement are present on vessels dating to the 5th millennium, therefore attesting the use of some sort of (nonsurviving) rotary device. The invention of wheel-shaping techniques, therefore, derived from an existing tool though by the 4th millennium it provided the technician a new source of energy. This is the exploitation of this new source of energy through new skills that makes the wheel-shaping technique a discontinuous development.

In terms of efficiency, when compared with the coiling technique the wheel-shaping technique hardly saves time. According to our experiments (Roux and Courty, 1998), the difference between the two techniques hardly exceeds 15 min. Indeed, because in both cases roughouts are made by coiling, the same amount of time is spent forming, building, and joining the coils through hand pressure. The wheel only saves time during thinning and shaping operations. However, these operations are not so fast because it takes time to transform a heterogeneous roughout into a homogeneous body and to erase traces of where the coils were joined. Our experiments suggest that, on average, a pot made without RKE takes 1 hr, and with RKE it takes 45 min. Even though these experimental results are particularly long, they provide a reference database with which to assess the relative efficiency of each technique. The real difference between the two techniques is qualitative: products made through wheel shaping are characterized by more regular and “stretched” walls.

The skills involved in wheel shaping are the same as those that have been described already for the wheel-throwing technique (Gelbert, 1997; Roux and Corbetta, 1989). They are characterized by a stability in the forearms (which are asymmetrical relative to the axis of the wheel), and by two-handed bilateral control. Motor control of the two hands involves applying regular and constant pressure and modulating these pressure according to the plasticity of the clay, the speed of the wheel, and the shaping operation. Importantly, the skills involved in wheel shaping take a particularly longer time to acquire than do the skills developed to effect the coiling technique. This is because the latter are close to gestures practiced in everyday life (Roux and Corbetta, 1989). Several years—some 10 years, based on empirical data—are necessary to master the wheel-shaping skills necessary for crafting vessels of all shapes and dimensions. Recent psychological studies (Ericson and Lehman, 1996) have shown that, generally speaking, 10 years is “the golden rule” for developing either a purely cognitive expertise (e.g., to play chess) or a motor one (e.g., playing a sport).

Environment

Our comprehensive study of the clay materials identified in the Chalcolithic ceramic assemblage from Abu Hamid determined and classified the raw materials, their properties, and their modification by human actions (Roux and Courty, 1997). The properties of the fine (clay) mass and coarse inclusions in the archaeological
ceramics were compared with a reference database of superficial deposits and soils available in the Jordan Valley during the Chalcolithic. This database is the result of a detailed stratigraphic soil survey aimed at establishing the evolution of Jordan Valley paleogeography at a microregional scale during the Neolithic and Chalcolithic periods (Hourani and Courty, 1997). The survey enabled us to determine that the catchment basins of each tributary of the Jordan River and of the upper, middle, and lower parts of the Jordan Valley itself presented specific geological and geomorphic configurations. These configurations are clearly shown in marked contrasts between the sedimentary facies of the various late quaternary alluvium and slope deposits. Therefore, the mineralogy, petrography, and texture of the fine clay mass and coarse inclusions—observed in thin section—proved to be diagnostic criteria for identifying the geographic source of the raw materials.

Nine groups (sources) of clay were identified (Roux and Courty, 1997). Significantly, 90% of the V-shaped bowls from Abu Hamid appear to have been made from one specific clay source found not in the Jordan Valley or surrounding basins but from a locale well known in the Negev (Roux and Courty, 1997). This indicates that the overwhelming majority of wheel-shaped bowls was made with clay imported from the Negev—some 150 km away. In contrast, the remaining 10% of wheel-shaped bowls recovered from Abu Hamid appear to have been made from various clay found either very near the site or from other regions of the Jordan Valley. These various clays were also used to make non-wheel-shaped vessels. In addition, some wheel-shaped vessels were made from clay mixtures, proportional compounds intentionally blending together clays coming from multiple locales. The most striking of these were detected by petrographic anomalies marked by the presence of exogenous coarse inclusions known to come from regions other than those providing the coarse components and fine mass. Yet more subtle anomalies in the mineralogy of the fine mass indicate that clays of different origins were indeed mixed (Roux and Courty, in press).

From these data one may conclude that the properties of clay materials did not play a determinant role in the differential use of RKE, nor did their provenance determine the spatial distribution of production centers. As well, different clay materials were used to fashion V-shaped bowls from sources both nearby and far away, although the bulk of them were made from the most distant clay sources.

The preparation of clay materials was not differentiated according to shaping technique either. In general, clays were extremely well prepared for ceramics fashioned both with and without RKE. Among these two technical groups, only 10% of the cases were made from clays that were little prepared (Roux and Courty, 1997).

**Intention(s) of the Subject**

The subject’s intention(s) may be understood through the function of the end product. In other words, the function of a pot represents the potter’s ultimate aim when he makes a pot. Function can be inferred from a combination of intrinsic
and extrinsic data. In this case, intrinsic data are the properties of V-shaped bowls, and extrinsic data relate to the context of deposition/use.

**Intrinsic Data**

First, evidence shows that the wheel-shaping technique was restricted to the manufacture of V-shaped bowls. Now, the use of local clay materials for fashioning V-shaped bowls indicates that there were potters at Abu Hamid who did know how to shape pots on the wheel. Once the requisite skills were developed, they could have been—but were not—applied to the production of other vessel shapes. Indeed, the absence of any transfer of wheel-shaping techniques to the entire corpus of vessels from Abu Hamid cannot be explained by technical problems related to the preparation of the clay or to characteristics of the tool. In terms of clay preparation, the same clay materials prepared in a comparable way had been used for shaping vessels with or without RKE. And as mentioned earlier, in terms of the wheel itself, the smaller the diameter of the bowl the faster the wheel should rotate. Given this, wheels used to manufacture small bowls also could have been used to make vessels of different shapes and sizes. Combined, these observations lead to an initial hypothesis: because there was no transfer of wheel-shaping techniques to the chaîne opératoire of non-wheel-shaped vessels, it is reasonable to hypothesize that the function and/or status of V-shaped bowls differed from all other vessel types.

Second, the decision to use RKE to shape V-shaped bowls cannot be explained in terms of efficiency. Indeed, experiments show that this technique is not significantly faster than the coiling technique. Moreover, estimations for the total number of wheel-shaped bowls produced and consumed each year at Abu Hamid—130/year—suggests that their rate of production was very low (Roux and Courty, 1997, p. 39). These computations take into account (1) the number of sherds and bowls found in the upper layers of the settlement (1,276 sherds identified as wheel shaped and 35 whole bowls distributed across the 1,200 m² excavated area); (2) the proportion of excavated area (5%) relative to the total surface area of the site (2.5 ha); (3) that each sherd represents one vessel; and (4) that V-shaped bowls were present in the same proportions all over the site. This formula yields a grand total of 26,000 bowls divided by the entire time period covered by the upper layers—some 150–200 years—or the annual production of 130 vessels. Making 10 pots/day, one potter could achieve this yearly output working just 13 days. Similar production rates may be ascertained for contemporary production centers (Goren, 1995), such as those in the Negev, and allow a second hypothesis: the very limited production of V-shaped bowls. For example, at Abu Matar (Commenges-Pellerin, 1987), a 1,500 m² site occupied for 200 years, excavations recovered 883 sherds and 230 complete wheel-shaped bowls, or no more than 1,113 vessels produced during some 111 work days); during excavations of more than 8,000
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m² of surface area at Safadi⁹ (Commenge-Pellerin, 1990), similarly occupied for 200 years, 11,908 sherds and 2,453 complete wheel-shaped bowls were recovered. We suggest that these finds correspond to the manufacture of 14,361 vessels which manufactured over a total of 1,400 days, or as little as 14 days/year, spread over a century.

In quantitative terms, therefore, one cannot correlate wheel-shaping practices with a need for mass production. On the contrary, if one considers the skills involved in the manufacture of V-shaped bowls, the wheel-shaping technique seems to associate with the manufacture of “exceptional” objects.

Third, at Abu Hamid, the evidence shows that 90% of the wheel-shaped V-shaped bowls were made of clay imported from Negev, even though appropriate clays were available locally. Indeed, V-shaped bowls fashioned with local clays are only present in very small numbers.

Extrinsic Data

With respect to the context of deposition/use, V-shaped bowls have been found not only on habitation sites, but in funerary and ritual contexts: As well, V-shaped bowls represent 50% of the ceramic assemblage found in tombs along the coastal area (Perrot and Ladiray, 1980); in the necropolis of Shiqmim, where Levy and Holl (1988, p. 296) observe that “it seems that every individual was buried with at least one V-shaped bowl”; and in the sanctuaries of En-Gedi and Gilat, where they constitute the great majority of vessels (Goren, 1995; Ussishkin, 1980).

Thus, V-shaped bowls appear to be “exceptional” objects with a status and function distinct from other contemporary vessels. They were used in contexts associated with rituals, and at Abu Hamid, their raw material was mainly imported. It follows, as a final hypothesis, that V-shaped bowls were not restricted to the domestic sphere, but were also used in ritual/religious activities (Fig. 3). Following Walker (2002, p. 161), religion is here defined as the “extension of the field of people’s social relationships beyond the confines of purely human society,” this definition enabling us to envisage socioreligious activities involving artifacts.

The Context of V-Shaped Bowl Production

The context of ceramic production is here defined in terms of economic and sociopolitical organization.

First, given the skills necessary for making this type of vessel, the potters responsible may be considered specialized craftspeople. This inference calls upon the following hypothesis: in contexts with multiple technoeconomic activities (such

⁹Ratio surface of the site/surface excavated is not known.
as ceramic production), those activities whose successful performance depends on skills developed during long-term apprenticeships are conducted by craft specialists (Roux, 1990). Given quantitative data (above) related to the low level of production and use of V-shaped bowls at Abu Hamid, one can suppose that there were very few specialized craftspeople involved. This hypothesis is supported by the fact that mastering a technique demands a certain frequency of practice which could not have been achieved if production had been shared among numerous potters. Note the paradox here: a specialized and small-scale production activity requiring specialized skills, found on most late Chalcolithic sites in the southern Levant. In fact, on the basis of analysis of clays and related technical evidence, recent macroregional research suggests that the few craftspeople producing these V-shaped bowls were itinerant (Roux and Courty, in press), which would help make sense of the small scale of production identified on most Chalcolithic sites in the region. The ritual role of the V-shaped bowls also suggests that these few craftspeople were attached to elites. Indeed, demand for ritual objects was likely generated by a politicoreligious elite. A second hypothesis is thus plausible: the specialized potters who produced these ritual objects over the entire southern Levant were linked to an elite class, though specifically how they were linked remains unclear.

The hypothesis that specialized potters were attached to a politicoreligious elite is supported by the distribution network of V-shaped bowls. At a macroregional scale this network reveals a structural link connecting individual sites. More
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precisely, as Levy suggests (Levy, 1998; Levy and Holl, 1988), the privileged relationship between Abu Hamid and the Beer-sheva nahal area in the Negev (the source of most of the clay used to make V-shaped bowls) indicates the existence of a vast politicoreligious community distributed across the entire southern Levant, dedicated to integrating different groups.

A Dynamic Interpretation of the Emergence of the Wheel-Shaping Technique

At the beginning of the 4th millennium BC a new ceramic technique appeared, the wheel-shaping technique. This technique originated from an interaction between an invention—the use of RKE for fashioning clay walls—and demand for a new kind of vessel.

The emergence of the RKE technique is rooted in the internal evolutionary potential of rotary devices. Indeed, when a rotary device is used to facilitate the potter’s work, its physical characteristics produce RKE. The very invention of the wheel-shaping technique consisted of using RKE to transform clay walls in a new way. For the individual potter, the efficacious properties of rotary devices were discovered in concert with the development of new technical skills. In other words, the potter came to perceive relevant properties of the rotary device (RKE) and to produce appropriate skills to transform clay walls with the help of RKE. Invention of the wheel-shaping technique was achieved, at the individual scale, through the dynamic interplay of all these components in an ongoing perception–action cycle. Importantly, this technical invention does not bear either on the method or on the tool itself, given that the rotary device had already been invented. Rather, adoption of the technique is characterized by properties discontinuous with tradition, because it implies a long period to learn new skills.

At the scale of the social collective and of history, there was a new demand for vessels of “exceptional” value, interpreted here as ritual, during a time of politicoreligious change. In dynamic interaction with the invention of the wheel-shaping technique, the concept of “exceptional” value became associated with the wheel-shaping technique, and thus potters constructed the cultural representation of “exceptional” value in terms of technique.

In a typical hierarchical methodology, one would first suggest the invention of the wheel-shaping technique followed by a demand for exceptional objects made in this fashion. In other words, one would suggest a causal variable for explaining the transformation of the invention into an innovation. Alternatively, from a cultural (or even a marxist) perspective one might suggest that the innovation of the wheel-shaping technique could respond to a technological choice in agreement with a “worldview” (supposing a preexisting cultural representation). But in this case, the technological choice could have been motivated, for example, by the desire in a changing world to create new techniques which only some potters could learn.
In other words, it could have been in the economic and social interests of certain elites to support such potters, and thereby enhance their politicoreligious status.\textsuperscript{10}

Using a dynamic systems framework, innovation of the wheel-shaping technique is understood to have emerged from the complex interaction of invention and external demand. In this evolutionary process, a technique and demand for its particular end products have the same “status,” recursively acting upon each other in the development and adoption of the new technique. One does not need to invoke preexisting cultural representations, compromises between different factors, or else external variables at the origin of new representations and new choices. In other words, one does not need to invoke external and/or internal motivations. The dynamic metaphor proposes to consider, on the basis of empirical data (which is a major point), what are the components of the system from which the phenomenon of innovation has emerged.

The dynamic conditions of this innovation are found in the context of production. The demand for ritual bowls included their production using specialized techniques provided by artisans attached to an elite. Such demand also came during a time of politicoreligious change, which implies new material culture needs. In other words, two main parameters, in concert with each other, account for the dynamic conditions actualizing innovation of the wheel-shaping technique: (1) the existence of specialized potters attached to an elite and (2) a demand for new vessels of ritual value in keeping with radical political and religious changes (Fig. 4).

By distinguishing on the one hand analysis of the conditions for actualization of technical innovation, on the other hand analysis of the mechanisms underlying the phenomenon of innovation, one may propose hypotheses on technological evolution whose context of validity can be tested, in the future, through comparative studies. One may thus ask to which extent, in ancient times, the emergence of wholly new technological facts which broke with tradition necessitated at least these conditions. On the contrary, studies which strive to unravel all the different parameters at play into a technological fact not only face methodological difficulties, but also cannot lead to comparative studies because they necessarily highlight only particular cases (total social facts being by definition local and then particular).

\textbf{CONCLUSION}

The dynamic systems framework allows us to question both the \textit{process} of technological evolution and the \textit{conditions} enabling this process. By analyzing the innovation of the wheel-shaping technique in the southern Levant through this perspective, it has been possible to show that this particular technological fact

\textsuperscript{10}A perspective suggested by M.-A. Dobres, among others.
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Fig. 4. Schematic model promoting a dynamic interpretation for the emergence of the wheel-shaping technique.

originated in the dynamic interaction of an invention and the demand for ritual objects, while it was actualized in a context defined by two main parameters: the existence of specialized craftspeople attached to an elite, and a demand for newly invented vessels taking place during a time of significant politico-religious change.

Applying the dynamic systems framework to the study of technology allows us to escape the methodological dilemma which requires the researcher to distinguish between technological and social entities, while simultaneously overemphasizing the sociocultural dimension of the technological fact. To explain the latter, the dynamic systems framework stresses the role of equal interactions between different components, explaining the construction of cultural representations of these technological facts as emerging from this interactive process. It also stresses the idea that conditions actualizing a technological fact can be defined by a
limited number of parameters. Thus it is no longer necessary to invoke the entire sociocultural system.

Over the long term, the dynamic systems framework should enable us to develop a better understanding of how comparable technological phenomena can emerge in different sociocultural settings. Indeed, the evolutionary potential of techniques is considered here not according to an evolutionary paradigm, but as an emergent property and equal participant in the dynamic, right alongside the subject and his or her situation in the sociocultural domain. In different sociocultural settings, we suppose that the dynamics of the technological fact can, thus, operate in similar ways for comparable evolutionary properties, intentions, and contexts of actualization.

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