Biological Oscillators, Circadian Clocks, and Sacred Time: Prayer and Caregiving in Neurosociological Perspective

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March, 2007

'Paper prepared for meetings of the WG03 (The Body in the Social Sciences) of the International Sociological Association, The Abbey of Farfa, Italy, March 2007. We are indebted to Curt Cadorette for helpful guidance before this paper was written. FIRST DRAFT: NOT FOR QUOTATION OR REPRODUCTION WITHOUT WRITTEN PERMISSION OF THE AUTHORS.
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“Primitive prayer is no soliloquy, no meditation, but a cry to God. Face to face with an ‘I’ is a ‘Thou,’” with man another manlike being…. In keeping with the anthropomorphic character of God[,] this intercourse takes place wholly in the form of men’s social relations with one another. Prayer is…the reflex of human social relations.” Friedrich Heiler (1933).

To the German theologian Friedrich Heiler, the defining feature of religious life was prayer, the subject of his justly famous dissertation, Das Gebet (Munich 1917). Setting his subject in comparative and historical perspective, Heiler treated prayer as a “social phenomenon.” In his view, it was continuous with social forms found everywhere—“appeal and address, greeting and benediction, complaint and petition, praise and thanks, invitation, allurement, persuasion, threatening, insult, accusation, and apology (1933: 58).” How else were men to relate to an “anthropomorphic God,” he asked, except by employing the language of social life—the terms of their relationships, attachments, and interactions with one another? Deity was creator, parent, ancestor, progenitor, begetter, and protector—communion with Deity, family life re-imagined and projected. So much seemed obvious. But didn’t this equivalence also point elsewhere—to hidden causes religion shared with social life more generally? At a minimum, if the central subjects of religion equaled those of attachment and social
interaction—if the two subjects were continuous with one another—then explanations applying to one ought also to fit the other.

In 1921 when Heiler’s *Das Gebet* ([trans. 1932] 1958) was first published, the study of interaction was a new field. It had barely assimilated Simmel’s (1950; 1971: 41-141) essay on the dyad and the triad, more or less come to terms with the subtleties of face-to-face behavior that were to become its subjects over the next eighty years. Accordingly, there were limits on what could be said about the commensurability of prayer and the forms of social interaction. Since the 1920s, however, these limits have gradually been expanded, and the study of interaction has developed in ways that could not have been foreseen by Heiler or his contemporaries. Not only have there been important conceptual developments, but the subject itself has been opened to research from other fields, most recently biology and social neuroscience.

What the biological sciences have to say about social interaction or religious phenomena has gathered a skeptical but growing audience among social scientists. In the last decade, for example, sociologists of religion have witnessed the appearance of powerful new perspectives on religion from evolutionary biology and psychology (Wilson 2003; Atran 2002; Wright 1994; Boyer 2001; Ridley 1996). Yet much of this work has failed to penetrate mainstream sociology, chiefly because it stops short of providing specificity—physiological,
neurological, psychological—to social mechanisms that are rooted in evolutionary adaptation. One prominent exception to this appears in work from social neuroscience.\(^1\) Research into the biology of caregiving, for example, has shown how attachment and synchronization in infant-caregiver dyads are governed by innate hormonal mechanisms. Interestingly, these mechanisms have regular cyclic features that are correlated to circadian clocks, indicating that they have evolved against a background of the same circadian forces that are associated with oscillatory patterns in many natural systems. Surprisingly, however, mechanisms of circadian synchronization have received little attention from the social sciences.

In this paper, we want to take up Heiler’s project in relation to these mechanisms. Prayer, in our view, finds its roots in the same forces that unite a mother to her newborn infant. As we shall see, the organization of caregiving dyads is marked by cyclic patterns. In the first weeks of life, these patterns reflect endogenous biological oscillators that operate by means of caregiving—cyclic hormonal fluctuations, in both mother and infant, associated with breast feeding, holding, and attachment behavior. Thereafter, these same fluctuations appear in concert with cues arising from exogenous circadian shifts between night and day. Fundamental patterns in social interaction, and analogous

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\(^1\) Excellent examples of this work are presented in Cacioppo, Berentson, et al. editors (2002).
patterns in prayer, reflect the work of these underlying mechanisms of synchronization. Looking for these patterns can help to ground our understanding of religion, extending Heiler’s project, further naturalizing Durkheim’s, and providing new analytical tools derived from human circadian biology.

SOCIAL SYNCHRONIZATION AND CIRCADIAN CLOCKS

Why are we fatigued at the end of each day? And why does the morning light cause us to awaken and to feel alert? Common sense would seem to have one answer—we are tired at the end of the day because we have worked, and we are alert in the morning because we have rested. Yet there is something deeply biological about this daily change that takes us beyond what common sense can explain. Night and day, darkness and light are the markers of a circadian clock to which biological systems of all kinds are entrained. The physiology of circadian clocks extends into our personal and social life in ways we are just beginning to understand. Humans are eased toward sleep by soothing neuroendocrine activity triggered in them by darkness, and they are awakened and made alert by reverse hormonal surges brought on by daylight.

Seen in relation to alternating light and dark phases in each day, activity and rest, eating and sleeping, work and relaxation are circadian sub-harmonics—rhythms in the organization of personal and social life that are slaved to a master circadian clock. Understanding how these sub-harmonic patterns emerge, and
grasping how they are central to the integration of the social world, entails
recognizing the redundant ways biological systems are integrated with social
life—how, on the one hand, human physiology constrains social life and how, on
the other, social life regulates physiology (Smith and Franks 1999; Cacioppo and
Berntson 2002). The effects of circadian clocks, it turns out, are mainly mediated
physiologically by activity in the arousal system—by elevating or damping activ-
ity in the hypothalamic-pituitary-adrenal (or HPA) axis.

To glimpse the importance of circadian forces in the organization of social
life, consider the families of newborn infants. The adjustment of a newborn to
its parents’ sleep-wake cycles illustrates how circadian synchronization can be
crucial to the functioning of a family—and, by implication, to other social sys-
tems, as well. Prior to the newborn’s synchronization, families pass through a
period of unfamiliar disturbances and disorganization. The newborn wakes and
sleeps on its own schedule, its cycle primarily driven by an internal hunger clock
(see Fig. 1b). These hunger-driven cycles are unsynchronized with the basic
sinusoidal pattern of its parents’ sleep cycle, shown in Fig. 1a. What results is an
entrainment of the adult circadian pattern by the infant’s hunger clock, an
outcome that can be graphed with the distress-driven square wave shown in
Figure 2.

INSERT FIGURES 1A-1B, AND FIGURE 2 ABOUT HERE
This dramatically illustrates what typically happens in the family of a newborn during the first weeks after parturition. During this time, the infant rules. Its demands for feeding appear in a cyclic pattern of distress. And so dominant is this distress that it entrains and overwhelms its parents’ own circadian clocks, trumping their own needs for sleep. At the first sign of the infant’s hunger, parents dutifully awaken, their sleep interrupted in the regular but abrupt pattern that is represented by the square wave oscillation. In effect, the newborn is a source of harmonic interference, producing these abrupt phase distortions in its parents’ established circadian rhythms. This lasts until the infant is able to process light signals, after which synchronization begins to emerge. When synchronization appears, families then stabilize into arrangements of regular caregiving, reacquiring orderly properties they had before their newborn’s birth.

Much of this change has to do with stress. So long as a baby’s sleep cycle doesn’t correspond to its parents’, there is a cumulative increase in the stress a family must manage. Even when parents pool responsibility for the care of their baby, they still lose sleep. Quite literally, they become worn down; and if they become chronically fatigued, they risk immune compromise, illness, and depression. The effects of failed synchronization then spill from the family into adjacent settings, as when related kin are recruited by overtaxed or incapacitated
parents to provide relief through baby-sitting or other household functioning, or as when a fatigued spouse’s performance at work jeopardizes their employment.

As if in anticipation of these matters, evolution has provided compensating mechanisms. A mother who breastfeeds her infant, for example, produces in herself hormonal changes that can damp the effect that stress would otherwise have on her HPA-axis (Heinrichs, Neumann, and Ehlert 2002). This in turn allows her to bear a greater stress-burden than she otherwise could, benefiting her marriage and also supporting her capacity to prime her infant’s own immune system through the substances present in her breast milk. But if she is seriously stressed, by contrast, stress hormones in her breast milk will be transmitted to her baby, stimulating its own HPA-axis and further throwing the baby’s sleep-wake cycle out of synch with her own.

Because a newborn’s brain is not yet able to process light signals in the way an adult can—where, in natural settings, light triggers arousal and darkness causes physiological changes that induce sleep—the baby depends, during the first weeks of its life, on the substances in its mother’s breast milk to damp its own states of arousal and to allow it to sleep. Only when its brain has developed further will external light entrain the endogenous biological oscillators that, until then, had been governed by hormones in breast milk. Waking and sleep-
ing, hunger and satiation, activity and rest, will then be “slaved” to the exogenous circadian clock whose rhythms are marked by daylight and darkness.²

Ultimately babies begin to sleep when their parents sleep, and they awake in the morning when their parents awake—or nearly so. And when this shift occurs, the amount of stress in the family system begins to subside. Like communities that have weathered a crisis—towns where storms have passed, regions where disasters have been overcome, states from which invading armies have withdrawn—structural changes then begin to appear in families that reflect an easing of life. As in the discussions of threat-rigidity effects (Straw, Sandelands, and Dutton 1985), families can become more resilient and more flexibly organized—less importance needs to be placed on short lines of communication, they can open themselves to the outside world, re-integrate into wider communities, and they can process increased amounts of information. Life becomes easier.

Attachment mechanisms and circadian pacemakers

This relationship between hormonal activity and stress-buffering hints at how circadian pacemakers are integrated more generally with the functioning of social systems. Before there is circadian control in the rhythms of a newborn’s day, there are neuroendocrine controls that arise through the effects of maternal

² We shall speak here of master-and-slave relationships among coupled oscillators, employing the usage developed in the literature on synchronization and nonlinear dynamics. See Pikovsky, Rosembloom, and Kurths (2001); and Strogatz (1994, 2003).
caregiving. But ultimately these endogenous chemical regulators of waking and sleeping, activity and rest, come under the control of exogenous signals of light and dark. Several features of these endogenous mechanisms of caregiving are pertinent to understanding caregiving dynamics both in families and in other social systems.

**Immune Function.** There is a striking sense in which, as we have shown in previous work (Smith and Silon 2005), the mechanisms active in infant-caregiver interaction are really extensions of the human immune system. Distress in social life recruits analgesic resources to sites of “inflammation,” the same way an assault on the body will also recruit analgesic substances (principally endogenous opioids functioning as cytokines) to inflamed tissue (Bildack 2000). Interaction and attachment, in this minimal sense, are social extensions of an innate immune function. They modulate inflammation—whether the cries of a baby or the sting of bee. The mechanism behind this effect, as we have modeled it in formal terms, is a neurosociological oscillator. Represented schematically, the mechanism takes the same form as a chemical hypercycle—a model of coupled dynamics among autocatalytic or cross-catalytic reaction sets.3 The first models

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3 Hypercycles (see Eigen and Schuster 1979) bring about a coupling of two (or more) autocatalytic or cross-catalytic sets in natural chemical systems. They sustain their organization by producing stronger and more efficient chemical dynamics, or stronger interactions, that would occur if their embedded cyclic components were disaggregated.
of the attachment mechanism were called hyperstructures, in recognition of this formal resemblance.

Hyperstructures are fueled by distress—by pain, by suffering, by hunger, by fear, by anxiety. And they work, in a way related to the immune system, by bringing about the release of endogenous opioids and other pain-modulating neurochemical substances—in effect, recruiting hormone-releasing and neurotransmitter-releasing behavioral resources to sites where distress has been detected. When infants cry, for example, this mechanism comes into play. The cry is a distress call, communicated to the mother, who responds with some form of attachment behavior—picking up the baby, holding it, feeding it. Both in herself and in her baby, her behavior has the effect of causing the release of endogenous opioid peptides. Morphine-like in their molecular structure, opioids yield soothing, analgesic effects in each of them.

In newborns, distress calls are signals akin to withdrawal symptoms—the same symptoms we observe in heroin addicts. That is, they arise as a function of downward fluctuations in core hormonal systems associated with comfort. These include, among others, activity in the body’s opioid system, in the oxytocinergic system, and in the HPA-axis. When activity in any one of these systems dips below a comfort-threshold (a level associated with equilibrium levels in each of these systems), newborns will exhibit distress—the sort of distress that
begins with mild uneasiness but cumulates in agitated crying. It is such a signal that moves a mother to attach herself to her baby. Depending on the form her attachment takes—whether, for example, merely holding the baby, or holding and feeding it—attachment then stimulates opioid activity, or opioids in combination with increased levels of oxytocin, either of which will have soothing effects. Other forms of anxiety—fussiness, say, or boredom—can indicate diminished levels of arousal, stimulating a mother to separate from her infant, with the effect of elevating activity in the HPA-axis. As these two forms of maternal behavior exclude one another—a mother cannot be both attached and separated at the same time—they constitute an oscillatory pattern.

INSERT FIGURES 3A AND 3B ABOUT HERE

Figures 3a-3b are schematics of the opioid cycle and the arousal cycle respectively. For the special case of infant-caregiver interaction, these two cycles can be understood as competing with one another; each cycle depends on one of the two mutually exclusive forms of maternal behavior, attachment or separation. The implications of these cycles can be grasped by reconsidering them in relation to the concept of a depot—a reservoir of neurochemicals (opioids or, for the arousal system, norepinephrine) that can be depleted or can be replenished,

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4 As discussed in various papers over the last decade: see, for instance, Smith, 1994, Smith and Stevens, 1994, 1996a, b, 1999; Smith and Benard, 2002; Smith and Silon 2005.
depending on the phase of cycle.\textsuperscript{5} The symbols $O$ and $N$ in these graphics refer to opioids and norepinephrine, respectively; $A$ and $S$ refer to attachment and separation; and the subscripts $i$ and $c$ to infant and caregiver. The opioid depot cycle, in Figure 1a, shows that opioid depletion, $O_i^-$, gives rise to withdrawal pressure in the infant, $W(O)$, This indicates a need for depot recovery, and stimulates maternal attachment, $A_c$, commencing at a depot threshold point we have called $O^*_i$. When this threshold is passed, maternal attachment accelerates depot recovery up to the depot maximum, $O^*_i$, where subsequent use of the depot again depletes it.

A comparable logic appears in the arousal depot cycle. Like an empty reading on a fuel gauge, $N_i^-$, the depot minimum, is associated with the gradual onset of pressures, $W(N)$, for depot recovery. When the $N^*_i$ depot threshold is

\textsuperscript{5}What is a depot?

In abstract terms, a depot is simply a reservoir of resources. In the context of studying complex systems, however, the concept of a depot is important and useful. With depots, or reservoirs of resources, systems have the ability to accomplish work, such as maintaining equilibrium, responding to various demands, or damping and distributing distress. Logically, depots also require associated depot structures that generate and store depot resources for later use and can detect when more resources are required. By identifying depot mechanisms and depot structures, and by analyzing their related macroscopic functions, it becomes much easier to understand and model the behavior of complex systems.

For example, the human immune system consists of a depot of multiple, specialized cell types (monocytes, lymphocytes, basophils, neutrophils, eosinophils). These cells arise from our primary blood-building depot structure, the bone marrow, a depot of stem cell-generating tissue. There are also associated central and peripheral immune structures, such as the thymus, spleen, and lymphatic system. Our immune systems respond to, and are recruited by, physiological distress. Also, since immune cells have a finite life, they must be constantly renewed, or the result would be eventual immune depot decay.
passed, maternal separation $S_i$ begins to stimulate depot recovery up to $N_i^+$, where use of the depot again gradually depletes it.

Hyperstructures couple these two neurosocial oscillators, and each then works in oscillatory anti-phase to the other. That is, when the depot associated with either system is depleted, the depot associated with the other becomes active; when the second depot in turn is depleted, the first again becomes active. The coupling functions to synchronize the infant-caregiver dyad, optimizing comfort. The complete coupled hyperstructure appears in Figure 4.

Figure 4 is labeled so as to draw attention to various forms of feedback and coupling at work in this mechanism. For example, we speak here of entropy pressures behind the metabolism of resources in each depot, indicating that the mechanism is driven by basic thermodynamic forces that appear both interpersonally and physiologically. This is the significance of the entropy sphere at the center of the mechanism—an acknowledgment of the pressures behind metabolism and replenishment of the depots. For example, “addiction pressure” appears in relation to the replenishment of both depots, and refers to the pressures behind both attachment and separation (or their various substitutes).

In the case of attachment, this is an obvious extrapolation from the morphine-like
structure of endogenous opioids. There are equivalent addictive liabilities associated with dependence on chemicals of the HPA axis or their surrogates.

Bringing the hyperstructure mechanism under circadian control depends on the growth of the infant’s brain, as we have said. But it also depends on the comfort that only interpersonal synchronization can create. Comfort, in this sense, is not a property of persons alone but of social systems, whether dyads or larger systems. In the dynamical model that describes the infant and caregiver, accordingly, comfort is an attractor, a social condition that draws persons into itself.⁶

*Caregiver-substitutes*

Eventually hyperstructures work within the framework of circadian controls. The equation whereby attachment behavior yields opioids and separation behavior yields activity in the HPA-axis, moreover, generalizes into a model of how attachment-related forms of behavior in diverse settings are also regulated by circadian clocks. The form taken by these generalizations of the mechanism depends on the characteristics of the caregiver substitutes themselves.

At first, of course, babies aren’t very good at taking care of themselves. But even in the first months of life, they can be seen to develop weak cognitive

⁶ More precisely, the attractor state is the outcome of combined effects from both the opioid system and the arousal system. When either system shuts down, there is a decay period when its effects continue to be lagged into the cycle of the other system—creating optimal combinations of arousal and soothing.
and emotional strengths that allow them to decrease dependence for their own comfort on the presence of their mothers. These strengths appear initially in behaviors that babies use to self-soothe or self-stimulate themselves—thumb-sucking and rocking, for example—but they come ultimately under the control of thinking. As thinking acquires increasing coherence over the first two years of life, memory and fantasy begin to become “places”—in effect, attractor states—a baby can turn toward to comfort itself. At first, these cognitive structures supplement in only small and insignificant ways the major direct effect of a mother’s attachment. But with increases in the child’s capacity to think, the tight coupling of mother and child via the hyperstructure mechanism is loosened. Eventually babies make use of all manner of caregiver-substitutes, and they begin to regulate their own internal states with increasing efficiency.

**STRUCTURES OF SOLICITATION**

What babies are doing when they cry is what family systems theorists (see Kerr and Bowen, 1987; Bowen 1978) say we all do when we are uncomfortable: We spread distress and anxiety into others. In effect, anxiety-spreading amounts to looking to others for a comforting parenting response. The structure of this solicitation is upward—toward a parent or someone unconsciously treated as such.
Prototype Instantiation and Transitional Objects

The upward structure of solicitation, of course, is also the structure of prayer. Children do not pray spontaneously—or, perhaps better said, they do not innately employ the socially constructed imagery of religious experience. Prayer in this sense is not innate. Yet the structure of their solicitation is inherently reverential, and good parents naturally inspire a child’s piety and devotion. Children are also natural believers. They characteristically engage in magical thinking about their parents’ strengths—imagined omnipotence and limitless capacity to protect and love them (Greenberg and Mitchell 1985). It is in the setting of this filial religiosity that many children also are taught to pray, a simultaneity that piggybacks prayer onto one of the natural processes by which children become cognitively integrated into a social world.

Prayer is associated developmentally with the process through which children find symbols for the emotional and cognitive prototypes of caregiving that begin to form in the first weeks of their life. The growth and instantiation of parental prototypes can be modeled formally within a framework drawing on the tools of neural network analysis (see, e.g., Smith, Stevens and Caldwell 1999), but there are also some classic forms of a similar argument.\(^7\) In Winnicott’s

\(^7\) We are deliberately oversimplifying here. A number of mental systems, not entailed by this argument, play a part in the de-coupling of interaction from external stimuli, as in children’s
(1965, 1971) an interesting way of imagining this process, for example, a child struggles to find symbols for the important prototypes and illusions that form in the course of its initial attachment to its mother. Winnicott called these symbols “transitional objects,” denoting thereby (in his language) “illusions on the way to becoming real.” Transitional objects—most famously, teddy bears and blankets—symbolized illusions that, in Winnicott’s sense, were being brought under the control of “social reality”—where, in the first instance, “social reality” equalled the child’s mother. So when a child allows a mother to participate, say, in telling a story about teddy (“Teddy seems happy today,” she says), the child is allowing its own illusions to come under exogenous social controls—in effect, moving them into a reality it begins to share first with its mother and thereafter with others.

A generalization of the same process is when a child learns to pray. In this case, a socially constructed ritual form becomes the vehicle for instantiating important prototypes associated with caregiving and attachment:

\[ \text{Now I lay me down to sleep;} \]
\[ I \text{ pray the Lord my Soul to Keep.} \]
\[ I \text{ should die before I wake,} \]
\[ I \text{ pray the Lord my Soul to take.} \]

interaction with “imaginary friends.” The cognitivist/evolutionary argument about this phenomenon are intelligently discussed in Pascal Boyer, Religion Explained (2001).
The child who kneels beside her bed to recite this bedtime prayer is following, at first, the words of a parent. They pray together—first the parent, then the child, in repeating cycles or stanzas. Like many other prayers, this one draws on the resources of poetry—it is music in words. So when the parent and the child are reciting the prayer, it is as if they were singing together—“making music together,” in Schutz’s apt expression (Schutz [1951] 1971). Prayer then embeds itself musically with caregiving, synchronizes the parent-child dyad, and yields some of the same soothing effects as direct attachment to a parent—effects that ease the way to sleep by triggering the release of endogenous opioids.

Interpret this bedside ritual in light of Donald Winnicott’s arguments about transitional objects. In a child’s world, there is a weak equivalency between God and the Teddy Bear. Each is the symbol for important illusions that otherwise the child holds onto, fearing that to release them would mean their loss and destruction. But so powerful are these illusions of greatness and security that they require symbols if they are not to remain formless and vague, slipping away each time they are needed. For every child, there is a natural worry about just this kind of loss. So the child is motivated to look outside of itself—into the “potential space” where it finds its mother. If the child’s mother is trustworthy and reliable—and if she is, in Winnicott’s phrase, “good enough”—the child will experiment with the scary idea that this “potential
space” between itself and her is a place where it can move the symbols of these important illusions, and where they will not be destroyed.

Children first talk to their Teddy Bears as they later talk to God. Their conversation embodies worries and wishes about love and attachment, boredom and anger, thankfulness and hope—about themselves, their mothers, their families in general, their pets and playmates. The fact that the child shares these symbols in company with a parent means that there is social validation for the instantiation: what might have seemed an activity without basis—mere fanciful play—instead finds grounding in the sharing of the experience with another—in effect jointly constructing and thereafter reconstructing the same instantiation.8

Recited together with a parent, the prayer then reaches back developmentally to a deep precedent—to the synchrony that emerges in infant-caregiver dyad.

PRAYER AS A COMMUNAL ACTIVITY

Cognitive psychologists speak of “joint reconstructions of autobiographical memory” (see Barclay and Smith 1993) to describe how two persons, interacting with one another, recall the shared past together, creating, as it were, a collective memory. Often, for example, each partner in a marriage can begin a sentence the other can be counted on to finish (Edwards and Middleton 1988).

Jointly reconstructing a past in this turn-taking style, they strengthen the narra-

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8 We have been influenced here by the superb ethnography, close empirical analysis, and insight provided in the recent essays of Tanya Luhrmann (see 2004, 2005).
tive organization of their shared world—a world over which the same stories can again preside. Without such collective memories, a family loses cohesion, a marriage its moorings, a community its history. Reconstructing them, therefore, is a way members find their way back to a past in which they were part of the same social and emotional world (cf. Halbwachs [1950] 1980). This is the togetherness that equals attachment, repairing the apartness that is separation. It also recapitulates the emotional integration of caregiving—the synchronization of infant and caregiver that is a universal attractor state in the human condition.

Prayer as a Clock. Coupling two or more persons in prayer is like bringing them into such a conversation—a conversation, moreover, in which each employs the same terms to construct a relationship to God. Individual prayer is one matter, collective prayer another. Individual prayer, as Heiler noted (1959: 64), is often a “spontaneous free outpouring of the heart.” But communal prayer synchronizes a community—it is an exogenous oscillator. When it is not mere “petrified ritual,” it draws into itself the emotions and feelings of communicants. Not only the words, the liturgy, the forms of prayer—the kneeling, the genuflexion, the propitiation, the call-and-repeat, the abasement—but the chanting and music of prayer serve this end. Prayer, ritual prayer especially, then becomes a master clock, slaving the subordinate rhythms of communicants’ worlds to itself,
occasionally to the point, as in some religious orders, of fighting against the natural, circadian clocks that are part of human physiology.

When prayer accomplishes this communal synchronization, it draws on the innate physiology of caregiving. Forces that unify a baby and its caregivers then draw communicants together into the same attractor state. As they pray in common, they raise the comfort of their world, augment its capacity to buffer stress, and locate themselves within the religious framework that Berger (1967) once said arched over social life as a sacred canopy.

_Sacred Time and Profane Time_

Time and the sacred are related as are synchronization and attachment. Durkheim’s argument was that sacred time depends wholly on social interaction. This was his point about the force of Society—how coming together in religious congregation strengthened individuals in proportion to their unification with others. Fueled by how interaction amplified arousal, these occasions eclipsed the distance persons ordinarily maintained from others, and produced a state of collective merger—not of one person with another but of the community as a whole. Also present on these occasions, and made to glow with their force, were unifying symbols of group worship—symbols, as Winnicott might have added, of significant illusions, thereby jointly instantiated and reconstructed.
Left behind during these moments of unification was profane time, the scattered condition of everyday life, ruled by instrumental and individualistic motives. Indeed, as Durkheim argued so forcibly, these two states compete with one another—they are “diametrical opposites.” And yet while matters sacred and profane do not come into contact with each other, the separation between them serves to motivate the shift from one to the other, and then back again. In the unifying phase, there is renewal and uplift, and men are strengthened and given courage by feeling morally and symbolically connected to others. In the phase of everyday life, men are separated from one another, and there is slow social disintegration that leaves persons again “structure hungry”—searching for collective renewal and reintegration.

Here then is the same oscillation at the level of community life that we find in infant-caregiver dyads—and, by implication, in all social life. Merger is followed by separation—time spent together by time spent apart. The difference is simply one of scale. At both levels of analysis, synchronized interaction yields social integration, and social integration strengthens the capacity of individuals and their communities to meet challenges and buffer stress.

AMBITALLENC AND RELIGIOUS ANALGESIA

Notably, however, what Otto (1925) and other religious scholars have said characterizes an encounter with “the sacred” is not the same as the comfort that
comes from successfully soliciting attachment. It is instead a complex subjective
state marked by feelings such as awe, respect, fear, and exhilaration. We are
drawn to sacred things but are equally fearful of them—or, put another way, we
exhibit a profound ambivalence in our attitude to them. Is this the same ambi-
valence that develops in a child regarding attachment and separation from its
parents? Separation unconsciously carries the risk of abandonment, just as does
disappointing or distressing a parent. So although a child is exhilarated by sepa-
ration, it also fears that separation will lead to being lost and alone.

Toddlers provide perhaps the most dramatic outward evidence of this
ambivalence. Their behavior—indeed, the whole “toddler phase” itself—is
defined by a pattern of oscillating attachment and separation. The toddler who
strays from its mother’s knee, running gleefully away, suddenly turns around,
looks over its shoulder, and abruptly rushes back to mother—and then this same
cycle repeats itself, again and again. Clinical observers say that this pattern is the
product of two competing worries—abandonment and engulfment. From a
neuroscientific perspective, each worry ought also to be understood as the
outward symptom of depletion in one of the two core physiological depots at
work in attachment behavior—the opioid system and the arousal system. Clinici-
cians speak of the first worry—the symptom of depleted activity in the arousal
system—as a “fear of engulfment,” and they speak of the second—the symptom
of depleted activity in the opioid system—as a “fear of abandonment.”

When engulfment reaches a certain threshold, a child will begin to feel worried; its own capacity to function as an autonomous, self-governing person is threatened. Separation behavior modulates this fear. Abandonment fears, correlatively, motivate attachment behavior, and attachment then mitigates the fears.

Toddlers are travelers. They are actually learning to use their own behavior, by contrast to their former dependence on their mother’s, to control activity in their own core brain systems; hence, they attach and separate on their own. This alternately stimulates the physiological depots associated with attachment and separation. The child plays at separation but stays within reach of its “secure base.” Later in life, this solution expresses itself in the struggle to find comparable mixtures of security and exhilaration—of comfort and arousal. These hybrid states, formed of optimal combinations of security and challenge, are what Mihaly Csikszentmihalyi (1990) has famously called “flow.” To this condition we are drawn, as we negotiate our way between alternate anxieties occasioned by excesses of separation and attachment, challenge and competence.

Distance Management

At the heart of this ambivalence, as it works out socially, is the problem of managing distance. How close shall we allow ourselves to come to others? And

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9 Engulfment also refers to that “loss of self” that Erikson (1968) once discussed as “identity diffusion”—a condition that produces anxiety about merger or being “absorbed” into another.
how close shall we allow them to come to us? Or, to put this in terms of the travel metaphor, how long can we remain attached to others, and how long can we remain apart from them? Durkheim ([1912] 1995: 214-215) says that any object inspiring respect produces such a dual motive of closeness and distance. Deference, he says, is “sacredness manifested in respect.” It draws us toward the persons we worship, because they instruct us: They provide us with models to emulate, rules to structure our lives, and moral governance that unifies our communities. But deference also requires us to see such persons as necessarily separate and fundamentally different from ourselves. By collapsing the difference between ourselves and them, we would only diminish their capacity to instantiate our ideals. Self engaging Other entails this necessary, functional dialectic.10 The Other provides the purchase for values and ideals—fuzzy, abstract, inchoate matters that require instantiation if they are not to remain imponderable, inaccessible, and unreal.

One of the neurosociological foundations of moral order is to be found in this mix of love and deference. In childcare settings, it manifests itself first in the way a child senses the disappointment of a loved parent. If its behavior disappoints or frightens a parent—if the child misbehaves or engages in a potentially

10 And it is much in keeping with what we have learned from neural network models about how the brain itself classifies incoming stimulus packages. It draws them into existing prototypes, which are thereby reinforced and deepened, and it segregates dissimilar information by forming separate minima on the neural landscape. Distance is managed by segregation.
harmful behavior, say—then the distress caused to the parent will communicate itself back to the child, following the same mechanism that communicates a baby’s distress to its parent. What this means is that evolution has attached a normative rudder to social interaction: When we cause distress to others, their distress feeds back to distress us, thereby leading us to change our behavior—to bring ourselves in line with behavior they don’t find discomfiting (Smith and Stevens 2001). Social interaction thus contains implicit pressures toward conformity and normative integration. These pressures do not require explicit or public normative rules—only the implicit standards and informal norms active in the lives of persons we interact with. (Of course, the same mechanism also communicates distress when formal norms and laws are violated.) “Normativity” in this sense is carried most directly by deference and love—admiration that keeps us respectful of others, and love that causes us to worry about securing their protection and attachment.

Because normativity is physiologically equifinal with attachment, it can likewise bring about the release of endogenous opioid peptides. Moral communities thereby change their comfort thresholds—they fortify their capacity to carry worry, suffering, pain, and anxiety. Like the mother whose breastfeeding damps the responsiveness of her HPA-axis to stressors, communities governed by normative forces likewise damp the effects of stress. Moral integration—in
the extreme, moral crusade—is evidence of the community’s response to anxiety, the way attachment is evidence of a mother’s response to her infant’s distress. Moral behavior is its analgesic.\textsuperscript{11}

\textit{The Inspiration of Prohibitions}. In religious settings, the dance of together-and-apart, closeness-and-distance, love and respect, is managed by rules and rituals. Durkheim, in his reflections about these matters, gave us an inverted version of the argument about normativity. He was at pains to suggest how contact with sacred objects, interactions with sacred entities, inspired prohibitions—the culture of renunciation, asceticism, and obedience that was outward evidence of sacredness manifested as respect. Society and religion, he pointed out, demand continuing sacrifices—“renunciations, abnegations, and separations from self.” They demand that persons are braced to suffering—not, he says, “arbitrary and sterile cruelties…but a necessary school in which man shapes and steels himself, and in which he gains the qualities of disinterestedness and endurance without which there is no religion (Durkheim [1912] 1995: 320).”

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\textsuperscript{11} While analgesia follows from the neuroendocriine effects of conformity, comfort in a community is also managed by expelling those whose behavior is discomforting. In this case, distance is likewise being managed—by sending the deviant away, banishing them from the community. Such banishment is supposed to make deviants hungry to return, as memory exerts its pull on their emotions—to return home and to gain the benefits of integration and attachment. The same effect is seen in travelers, who eventually are drawn home by hunger for attachment to significant others and to the scenes of their childhood. The toddler’s oscillation, over longer periods, reappears in those who journey far from their friends and families and homes.
and society do not merely educate men to endure suffering—they enable them to endure it.

THE USES OF SUFFERING

Is there not a contradiction in all this? On the one hand, there is the central adjuration in so much religious doctrine—that to find God one must deny flesh, body, and self; and yet, on the other, there is the physiology of the human species—that none of this denial would be possible, were it not enabled by the hidden logic of our bodies. It is not so much the disavowal of this contradiction as the masked acknowledgement of it that fuels religious discipline. In the Christian Bible and in some nonwestern religions, mortality and flesh are equated to one another. Salvation is then paired with the denial of the body, transcendence and holiness with abnegation and renunciation.

“For the wisdom of the flesh is an enemy to God: for it is not subject to the Law of God, neither can it be. And they who are in the flesh, cannot please God...and if you live according to the flesh, you shall die: but if by the Spirit you mortify the deeds of the flesh, you shall live. For whosoever are led by the Spirit of God, they are the sons of God.” Epistle to the Romans
This advice carries beyond the usual caution that faith and libido are uneasy partners. It is more akin to Plato’s thoughts about the aims of education—that proper training bends the mind to the ideal, fixes it on the gods. How shall this be accomplished? Ideally—and only by carrying this worrisome caution to its logical conclusions—religious communicants are being instructed, if not actually to live as monks, then to take the lives of monks as models—to give up worldly aspirations, surrender possessions, embrace poverty and hardship, devote themselves to labor and prayer, and disappear into the self-effacing obscurity of their community. “The logic of the Cistercian life,” wrote Thomas Merton ([1948] 1959: 378) about his first retreat to the Trappist monastery at Gethemeni, “was the complete opposite of the world, in which men put themselves forward, so that the most excellent is the one who stands out, who attracts attention.” If he had had any “supernatural common sense,” reflected Merton, he would have understood from the start the inner logic of the monastic vocation—its withdrawal from the world, its poverty, silence, scourging, obscurity, and suffering.

A religious life, so conceived, does not then seem particularly analgesic. More so, it impresses the onlooker as suffering orchestrated in the service of devotion. Lay up your treasures in Heaven, say the preachers, and you will find yourself drawn to God. "If any man would come after me,” said Jesus, “let
him deny himself, and take up his cross, and follow me” (Mark 8:34). Yet even in this adjuration to other-worldly asceticism, there is still, though unintended, the hidden logic of the body. For those who believe that the “wisdom of the flesh” leads them away from God, faith can be strengthened by systematically harnessing the body to God’s service. And this is what religious communities, through the stringent enforcement of their rules, often seek to do.

Just as circadian cues eventually entrain endogenous biological oscillators, so in religious communities exogenous oscillators of other kinds hold sway—sometimes at the expense of natural rhythms and genuine physiological requirements, sometimes not. In the opus Dei prescribed by Benedictine Rule, monks pray seven times a day, even rising from their sleep to offer prayers at night. These are not moments cued by circadian signals but by exogenous clocks—by gentle “callers” on their rounds, giving voiceless signals at the door of a monk’s cell. For the deep sleepers in the monks’ dormitories, there is first the rustling of their brothers when the signal to awaken is given, then, if necessary, silent encouragements to arise. In the outside world, still other exogenous pacemakers also entrain the circadian flow. For the faithful in Roman Catholic countries, an angelus, the symbolic voice of an angel, rings three times a day, at morning, noon, and sunset, inviting the faithful to recite the Prayer of the Incarnation. Elsewhere and in other traditions, the call to prayer is likewise a voice, a chime, a
cymbal, or some other signal that rings above the business of daily life and
brings the faithful to devotion.

When these signals are heeded, they synchronize a community in
prayer—and often in other, redundant ways as well. Music and chant are part of
prayer but they are also separable idioms of synchronicity, and have equivalent
effects. The same can be said for immersion in ritual and religious theater, often
to the point where, as in trance behavior, there is such dissociation and loss of
self that the religious actor is wholly identified with a symbolic figure—Christ
carrying the Cross, saints at moments of martyrdom, Ranga or Barong, the cassow-
ary, the crow, the jaguar, the white cockatoo, the kangaroo, the totem parakeet.
Merger, after some interval, is succeeded by separation, when the moment of
trance ends, common sense re-surfaces, and the sacred bleeds back into everyday
life, unifying the community of those who, formerly adrift in secular preoccupa-
tions, find themselves again freshly connected through their common devotions
and shared symbols.

Prayer itself, especially in the setting of a monastic life, seems to draw on
this deep human capacity for dissociation—on the same readiness to abandon
self and become the other (“taking the role of the other,” in Mead’s justly famous
phrase) that we find in children. One monk described a young postulant’s
entrance into the monastery at Gethemeni “by way of a kind of obituary (Merton
1959: 357).” Separation from the outside world, from former life, meant not just assuming an alias and hiding the real self beneath the monk’s cowl, like a government informant in a witness protection program. Entrance into the religious life meant death of a former self and birth of a new one. Prayer, constant prayer, and constant focus on the task at hand, supported this shift, suppressing the continuing encroachments of memory on faith and service.

“The thing that was most impressive was [the monks’] absolute simplicity. They were concerned with one thing only: doing the things they had to do, singing what they had to sing, bowing and kneeling and so on when it was prescribed, and doing it as well as they could, without fuss or flourish or display. It was all utterly simple and unvarnished and straightforward, and I don’t think that I had ever seen anything, anywhere, so unaffected, so unself-conscious as these monks. There was not a shadow of anything that could be called parade or display. They did not seem to realize that they were being watched—and, as a matter of fact, I can say from experience that they did not know it at all….The presence of other people becomes something that has absolutely no significance to the monk when he is at
prayer. It is something null, neutral, like the air, like the atmosphere, like the weather.” (Merton: 361)

So much absorption in the sacred indicates how thoroughly prayer can become a master synchronizer. Yet by slaving the day even to the music of these exogenous oscillators, religious communities also risk “drift,” the potentially self-amplifying deviation of their own clocks from the rhythms of the natural world, rhythms that evolution has made part of human physiology. The Benedictine Rule recognizes this in various ways, chiefly in such adaptations as seasonal shifts in the times at which various Offices are prescribed and, in a kind of local rule, in leaving the timing of still other obligations up to the Abbot. And yet there are few observers of monasteries who come away without having witnessed the symptoms of the monks’ sleep deficits.

COMING INTO THE LIGHT

A measure of the slaving of nature to religion is the near universal appropriation of light and darkness as religious symbols. In the Christian tradition and in other religious traditions as well, God is the Light, and coming to God is illumination. A man is awakened to God as he is awakened by the sun. Yet since God is the Light, it is not the morning sun that stirs the faithful into wakefulness—it is God. So long as the faithful walk in His path, God’s light shines
upon them. Yet how are the faithful to recognize waywardness? How is a person to walk in God’s path—to keep in stride with God?

Synchronize yourself to God was the admonition. Communal chant and prayer, as we have seen, yield their soothing effects by drawing on the same physiology that appears in the synchronization of a mother to her infant. They are practices that unify—creating the same kind of intersubjectivity that emerges in an ensemble, the result of “realizing” a musical score together. Or that emerges in a crew race, when synchronous rowing, sensed by each rower through the balance of the boat, maximizes the boat’s power and speed. And, just as in an ensemble it is exhibitionism that draws attention to the individual player, or, in the boat, a failure of balance that brings attention to someone out of synch, it is also deviations from synchrony that make a man stand out in the religious community. “Excellence [as a monk],” wrote Merton (1959: 362), “…was in proportion to obscurity: the one who was best was the one who was least observed, least distinguished. Only faults and mistakes drew attention to the individual.”

Thus, in the symmetry required by equating God with Light, a man who walked out of step with God was said to grope his way in darkness, able to see only as one might conjecture from the shadows in a cave. To be left in darkness was equated with a person’s death. So in religiously disciplined communities, even sleep was supposed to be entrained to God’s service. A practice invoked to
this end by St. Benedict was that monks slept in their clothes, a signal of their conversion away from the world and an expedient that would diminish the time from the caller’s signal to awaken and a monk’s arrival in choir (van Zeller 1958: 187). The rules were meant to return each monk to his community—to awaken him to his vocation.

How, then, was a man to know waywardness? Sensing other’s distress at his own bad behavior was indeed feeling the equivalent of the disapproval and distress of a parent when a child did something dangerous or wrong. But it also drew upon a different kind of knowing—sensing and feeling that one’s society, interaction itself, was unsynchronized. Behavior out of synch with others disturbed the unity of the community; it failed the boat on which a person rowed, or spoiled the fluid performance of their ensemble. It was to rock the boat and lose the race, or to grandstand while others played together. Or, to shift the metaphor, it was to unmoor the person from the harmony and moral compass of the community. Worst of all, it was to stand out. To a monk, this meant being conspicuous, like the nonconformist in Schachter’s (1951) famous experiments, attracting disproportionate attention to himself. The monastic life could tolerate no solo performers. Merton craved such obscurity. Entering the monastery for the first time, he “felt the deep, deep silence of the night, and of holiness enfold me like love, like safety (1959: 352).” He knew himself to be spiritually attuned
to the life he was about to commence—to be religiously musical, in Max Weber’s knowing phrase.

THE SIXTH SENSE

Behind the unification of religious congregations, then, there is this remarkable collective or “social sense,” the product of how master clocks sometimes wire us to others in synchronized interaction. This isn’t an effect of an organ or a structure—there is no social analogue of an eye or taste bud. And it is not a matter of fully conscious processing of the signals of asynchronous interaction. But it is nonetheless there—akin, surprisingly, to how the immune system senses something wrong in the body.

J. E. Blalock (1984, 2005), one of the leading investigators of human immune responses, has described the immune system itself as a “sixth sense,” meaning that it can plausibly be likened to organs or structures of the body that perceive threatening stimuli, detecting, in this case, invaders such as bacteria or viruses. Having registered one of these invaders, the immune system deploys its own cellular agents—complement proteins, cytokines, macrophages, neutrophils, natural killer cells, in combination with other chemical and biological players—as part of a concerted biological response to engulf and rid the body of them. Such pathogens are stressors, signaled at the site of their invasion by a growing inflammatory response that is orchestrated by the immune system.
itself—increased blood flow, recruitment of macrophages from the blood in nearby tissue, the release of cytokines and other chemical messengers of the immune system, and other effects as well. In turn, an important result of inflammation is the release and subsequent recruitment of endogenous opioids—chiefly, β-endorphins—whose effect is to reduce pain at the site of the invasion. Once the body (and the person) has been alerted to the assault, opioids then soothe and reduce the inflammation.

If social interaction and attachment are extensions of the human immune response, as we have argued, then the “social sense” stands on the shoulders of this physiological guard system, an extension of this sixth sense. We can infer this by virtue of the shared chemistry at work in each—by the fact that opioids can function as chemical messengers of the immune system (that is, as cytokines), and that each system recruits endogenous opioids to sites of inflammation or distress. In the case of the social sense, this occurs when distress has been detected in a network of linked persons. More remarkable still are the wave mechanics we can then begin to glimpse in synchronized social networks. Not only does an injured or anxious person’s distress recruit analgesic resources to themselves—opioids stimulated by others’ attachment—but links in networks, once generated or reactivated by the social response to their distress, then propagate the effects of attachment and interaction.
This can’t happen, of course, if persons aren’t linked in networks. Under stress-free conditions, most people are transiently able to function either without direct interaction or only loosely coupled to others in dyads. Their wider network links are latent or inactive. But when a stressor affects one of these persons, others in their network will get the message. Those who discern their distress will be entrained, and the network will then begin to function as an integrated oscillator. There are many examples of this kind of network activation in biological systems, when independent oscillators get coupled and work together in physiological synchronicity. In social networks, distress-activated links get organized in numerous, often complex interpersonal architectures—some, like wheels, embody hierarchy; others, like rings, are marked by holes and dead zones; still others, like railroad lines, string together terminals along linear paths. Most embody all these features in various small worlds. In neighborhoods of these clusters and in many complex hybrid topologies as well, synchronization will arise, its mechanics affected by network connectivity and by limits inherent in servicing the dual physiological depots in embedded dyadic couplings.

In synchronized networks, such as teams playing a coordinated game, ensembles performing a piece of music, or assemblies praying together, there are interesting though poorly described patterns of synchrony. The social sense gauges, through the soothing outcomes of synchrony, if the members of a com-
munity are coupled harmonically. When, say, a monk is out of synch with his brothers, this is registered as discomfort. It stresses the network, the same way members of a crew feel disequilibrium in their boat—by the small deviations from perfectly balanced rowing, when the boat begins to rock or to wobble, that interfere with the boat’s speed and course. This is a network effect—a kind of communication that can only arise when persons are linked.

The exact ways these and other network effects are locally propagated in networks remain to be more fully described empirically, but they clearly depend on network topology along lines that formal studies of networks are beginning to model. In real social networks, more than one pattern or channel of transmission can be involved—for example, to nearest neighbors and only then to others; or, as in persons linked by a prayer recited in unison, through a master clock that slaves an entire assembly to itself. Like Huygens’ two pendulum clocks, connected by a beam, persons will eventually re-synchronize, if their oscillations have gone out of phase. If they don’t, the neighborhood linked to them will experience increasing discomfort.

The social link, like the beam that coupled Huygens’ clocks, transmits the social equivalent of the pendulum’s vibrations, feelings that are evidence, not only of deviations from synchrony, but also of unification and rhythmic coupling

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12 On nearest neighbor models, and other formal approaches to clustering and “small world” topologies in networks, see essays in Newman, Barabási, and Watts (2006).
as well. Since these feelings can only arise through social ties, through the synchrony of persons linked in networks, it is reasonable to regard it at as an extension of the sixth sense discussed by Blalock—perhaps, as we have described it here, as a socially-mediated sixth sense. Such a social sense stands behind those phases of social life when assemblies, teams, and communities know themselves to be in step; but its origins, like the immune system’s, are in evolutionarily conserved neurosociological mechanisms fed by stressors, assaults, afflictions, and dangers.13

Partly, therefore, our distress-dependent social networks are evidence of how we have evolved as a species, wired together with others so as to optimize not only personal comfort and personal health but also to manage the neurosociological functions of our social life.

CONCLUSIONS

Nowhere is there better evidence of that “disinteredness and endurance without which there is no religion” than in formally organized religious commu-
nities. In the tradition of Western monasticism, a monk or a nun passes through the long trial of a novitiate in which they leave behind their former identity and assume a new one. The religious novice becomes a brother or a sister of an ordered community, part of a religious family. The monastic society St. Benedict sought to found departed from the model of the monk that had come from the East—the hermit who sometimes lived together with other hermits but was essentially a solitary figure. (The word monk itself came into English from the Greek μόναχος and, in turn, μονος, meaning alone.) But Benedictine monasteries were to be coenobitical, on the model of the Roman familia (Van Zeller 1958: 48). The forms of family life, as Heiler would have said, were ways to conceptualize this community.

Yet only obliquely do coenobitic communities harness the comforts of attachment in the service of their communal life. Renouncing or limiting direct attachment and interaction, they supplant them instead with indirect links and attachment-substitutes—with the moral uplift of ascetic discipline, the satisfactions of adherence to monastic rule, and the daily congregation produced by prayer, ritual, the reading of psalms, and music performed in unison. The effect of all of these practices is to fuel devotion and to bring about a profound synchronization of the community. Monasteries reverberate with chant, prayer, and song.
Monks are likely steeled to their asceticism by the neuroendocrine support enabled by their devotions, just as is the child reciting a bedtime prayer. But more than being supported in the face of privation, they are also enabled to carry the burden not of themselves alone but of a wider outside world that looks to them for care and instruction. And to the extent that life is short and mean, the lives they lead are models to outsiders scattered into profane callings. The monastery itself is a prayer magnet—a place drawing the outside world to itself for healing and religious comforts. It orchestrates sacred time, the way an ensemble realizes a score.

The fully religious life is a life of prayer. As we have tried to show in this paper, nothing about prayer renders it exceptional or privileges it. It is continuous with other natural phenomena—with other “social forms,” as Heiler said, found elsewhere in organized human communities. But the search for these continuities can take us far outside of religion itself—and outside of mainstream sociology as well. We have argued here that these continuities are neurosociological—that they emerge from innate mechanisms present in caregiving and social interaction. The extent of these continuities was impossible for Heiler to gauge in the 1920s. But we now have far better understandings of the physiology involved, and this knowledge can begin to breathe new life into their study.
At the very least, religious communities can be seen to harness in their service the same physiological mechanisms that shape attachment behavior. Durkheim, perhaps, would have been uncomfortable with this claim, because of the reductionism it entails. But we are less handicapped these days by the intellectual blinders his anti-reductionist stance fitted to sociology. The argument from social neuroscience is more compelling. Even Marx’s indictment of religion got some of it right: Religion, he wrote, is the opium of the masses. Better said, religious behavior recruits analgesic resources, among them opioid peptides, to sites of suffering, chiefly by organizing prayer as a form of social interaction.
Fig. 1a: Approximate Adult Circadian Rhythm
Idealized Sinusoidal Waveform
Master Solar (Light/Dark) Clock Entrain
Subordinate Clocks (Hunger, Hormone, Sensory, etc.)

In adults, hunger clocks are generally entrained to solar cycles. We wake with light until hunger inputs and sleep with darkness, satisfaction, and fatigue. However, these mechanisms are adaptive based on neurosocial inputs and prototypes.

Fig. 1b: Approximate Newborn (Circadian) Rhythm
Idealized Sinusoidal Waveform
Hunger/Hormone Master Clock
Emergent Light/Dark Response (After 1st 3 months)
Cedually Extends Daytime Waking / Nighttime Sleeping

Newborns wake up to feed (distress), then return to sleep after "attaching" and ingesting maternal breast milk. Breast milk also serves to synchronize newborn digestion. Eventually, early attachment-synchronized hunger and hormone drops become (and remain) entrained to master solar (light/dark) circadian input.
Fig. 2: Newborn-Driven Circadian Transformation
Forced Square Wave Conversion of Adult Circadian Sync
Newborn Hunger Clock Takes Over as Surrogate Master Input
Distress Drives Rising Edge - Infant Must Be Fed
Maternal Depot Resources/Exhaustion Drive Falling Edge
Conversion/Attenuation (fatigue) is the Measure of System Stress

Figure 3a: Opioid Depot Cycle
Figure 3b: Arousal Depot Cycle

\[ N^+ \Leftrightarrow S \Leftrightarrow N^- \]

\[ S_c \rightarrow N^+ \rightarrow N^- \]

- \( N^+ \) represents a competitive transition to noradrenaline depot dominance fueled by external social interaction.
- \( N^- \) represents a competitive transition to opioid depot dominance fueled by external social interaction.
- \( S_c \) represents caregiver separation, resulting in the decline of active infant noradrenaline depot levels.
- \( O_i \) represents a decrease in endogenous opioid receptor density, resulting in the decline of active opioid depot levels.

- Caregiver attachment (\( A_c \)) results in the decline of active infant noradrenaline depot levels.
- Metabolism/Entropy Pressure accelerates the transition from \( N^- \) to \( N^+ \).
- Addiction Pressure accelerates the transition from \( O_i \) to \( O^+ \).
- Social interaction (\( A_c \)) accelerates the transition from \( O^+ \) to \( O_i \).

Depot Utilization: [-]
Separation Event: +/-
Withdrawal Recovery: [+]
Depot Threshold Point: W(N)
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