Emotions and Facial Expression

Robert B. Zajonc's article "Emotion and facial efference: A theory reclaimed" (5 Apr., p. 15) calls for a reconsideration of Waynbaum's vascular reafference theory of emotion (*1*). Zajonc's strongest argument for exhuming this admittedly weak hypothesis is the supposed inadequacy of any Darwinian account of emotional expression. He offers in its place a reformulation of Waynbaum's fundamentally nonevolutionary views. Waynbaum's position is understandable, given the rationalist physiological and anti-Darwinian bias of French biology in his day (*2*). Zajonc's rejection of current Darwinian thinking is more puzzling. Like Waynbaum, he does not incorporate current thought on animal communication and social behavior.

To Zajonc it seems to be a paradox that humans, who possess language, should have evolved the most complex repertoire of facial movements. He asks, "Do we need, in addition to speech, some 80 facial muscles merely to broadcast our intentions?" Here Zajonc does not distinguish evolutionary origins from current adaptive function. A minority (probably less than one-third) of human facial actions reflects emotion or intention (*3*). Most facial actions are accompaniments to speech, spoken or heard. As Darwin put it, "The movements of expression give vividness and energy to our spoken words" (*4*). The elaborate human facial musculature has also been attributed to selective pressures for sucking, chewing, and vocalizing (*5*). Whatever its original purpose (nonverbal communication or even vascular feedback), our exquisite facial repertoire now serves primarily a paralinguistic function. When the distinction between origins and current functions of human facial actions is clear, there is no paradox left to explain.

Zajonc broadens his attack to include all Darwinian theory, bringing up the timeworn charges that evolutionary theory is circular, that it can account for any finding, and that it is nonfalsifiable. Rebuttals are available in many volumes on the history and philosophy of evolutionary biology (for example, *6*), which Zajonc does not cite. He also seems to mistake the limits of imagination for constraints on natural selection ("What purpose might be served by displaying one's own fear to an enemy, or one's own surprise to an intruder?"). Lest the reader ponder an evolutionary explanation, Zajonc points out that "such explanations depend on conjecture." Yet he praises Waynbaum's hypothesis as "a product of a superior imagination," constructed from "assumed processes, about which he could no more than make intelligent guesses."

Zajonc portrays Waynbaum's idea as a "radical theory of emotional expression, defying all previous ones, including Darwin's dominant theory." However, nowhere in his book does Waynbaum take issue with Darwin's evolutionary methodology. Several of his references to Darwin are laudatory, and where he does dissent, it is with respect to specific adaptive interpretations. This is much the same evaluation given Darwin by recent workers in facial expression (*5*). Waynbaum's postulation of an additional adaptive function for facial actions elaborates rather than vitiates Darwinian theory. If anything, evolutionary theorists have gone Waynbaum a step further by proposing that animals use displays to manipulate the physiology of conspecifics directly (*7*).

Despite Zajonc's disparagement of Darwin, a vascular theory of emotion may have merit. However, when examined directly, several of the theory's contentions prove untenable. Because it is difficult to discern whether Zajonc speaks for himself or Waynbaum, we present a few points without regard to their source:

1) It is proposed that the zygomatic acts as a ligature on the external carotid branches and "the slave action of the corrugator blocks the return blood" to produce positive affect. Electromyographic investigations of both weak and intense facial emotional expressions show that the zygomatic and corrugator usually act reciprocally (*8*). They rarely act in master-slave fashion. According to a vascular theory, the masseter, which adducts the jaw and is among the most powerful muscles in the body, should surely have the most pronounced euthymic effect. Yet jaw-clenching is not associated with positive affect (except during a good meal); it is recruited during expressions of anger.

2) It is suggested that "more cerebral blood means better brain work." Unfortunately, the blood-flow study Zajonc cites as corroboration (*9*) cannot sustain this interpretation, because (i) it involved neurological patients with impaired regional cerebral blood flow (rCBF); (ii) the normal controls did not show significant rCBF augmentation; and (iii) in the neurological patients, there was no correlation between mental performance and rCBF augmentation. Moreover, Zajonc has reversed the causal arrow. Heightened neuronal activity elicits increased blood flow (*10*), and not the reverse.

3) It is stated that migraine sufferers "make a variety of unusual mouth movements, such as licking lips and biting the inside of their cheeks," which may reduce extracranial vasodilation. Curiously, these buccolingual actions are not pathognomonic in any headache diagnostic system (for example, *11*), nor are they mentioned in the migraine study cited by Zajonc (*12*). Nor do we know of any formal evidence that migraine sufferers perform buccolingual actions more than other headache sufferers or, for that matter, those who do not have headaches. Additionally, xenon-133 inhalation studies of migraine have shown that the intracranial and extracranial circulations act independently (*13*).

4) It is proposed that a vascular theory of emotion can account for "hedonic subjective experiences," whereas facial feedback theory cannot, because feedback from facial muscles "only furnishes information about what the individual must have previously felt." On the contrary, facial feedback hypotheses assert that muscular feedback determines current emotion (*14, 15*). It is doubtful that vascular feedback would be more rapid than that from muscle proprioceptors or cutaneous receptors. In any case, tests of facial feedback hypotheses, which Zajonc does not cite, show little evidence that facial actions influence emotion (*14, 16*). Moreover, there is no evidence that patients with facial paralysis (for example, Bell's palsy) experience impaired affect.

Zajonc places great emphasis on the falsifiability of scientific hypotheses. He claims such for his modification of Waynbaum's theory. Yet it is unclear just how one would make operational, much less falsify, a theory that invokes cerebral blood flow, regional nervous system anesthesia, intracerebral hyperemia, ischemia, blood pressure, regional brain temperature differences, blood cooling in the cavernous sinus, tissue disoxygenation, temperature-dependent kinetics of neurotransmitters and enzymatic pathways, differential synthesis and release of neurotransmitters, heart rate, extracerebral flow strictures secondary to muscular ligation, and locally enhanced neuronal activity elicited by changed blood flow—all of which, according to the theory, increase or decrease in unspecified patterns across a range of emotional states. "Thus a particular pattern of regional blood flow, together with local rise and fall of brain

temperature, might enhance or impair the release and synthesis of different neurotransmitters and thereby produce different subjectively felt states." Eighty years after its interment, Waynbaum's hypothesis is no closer to empirical test, much less validation.

ALAN J. FRIDLUND
Department of Psychology, University of Pennsylvania, 3815 Walnut Street, Philadelphia 19104
AVERY NELSON GILBERT
Monell Chemical Senses Center, 3500 Market Street, Philadelphia 19104

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Darwin's followers have amassed a strong body of data that support the proposition that facial expressions serve significant biological and social functions. These functions, particularly evident in early development, are not discussed by Zajonc, who questions the adaptive value of the facial signals of emotion. Darwin's view of the relations between facial expression and emotion-feeling states (*1*) (which was incorrectly described by Zajonc), is represented in contemporary emotion theory and supported by substantial empirical data, whereas the Waynbaum-Zajonc model of the activation of emotion-feeling states is not.

The biological and social functions of facial expressions, their modification and minimization in ontogeny (*2*), their absence or dimunition in imagery-induced emotion (*3*), and the inverse relation between facial expression and physiological arousal that obtains under certain conditions (*4*) argue against the Waynbaum-Zajonc notion that expressions evolved solely for the purpose of acting as ligatures on blood vessels. Even if the Waynbaum-Zajonc model describes an effective mechanism for emotion-feeling activation, unlikely as this now appears, there is no reason to believe that it would be the sole mechanism for this function. Redundancy is a common theme in evolution, and it would be strange indeed if so important a function as emotion-feeling activation were left to a single mechanism. Contemporary proponents of the Darwinian-type sensory feedback model for the activation of emotion-feeling states hold that other activation mechanisms emerge with maturation and learning (*5*). They also maintain that facial expressions have multiple functions that change ontogenetically.

When one considers all the evidence on the relations among facial expression, physiological arousal, and feeling state, it appears that facial expression can amplify or attenuate (or even become dissociated from) related physiological and phenomenological processes (*2*). Such a flexible role for facial expressions is consistent with neo-Darwinian views, but difficult or impossible to explain with the Waynbaum-Zajonc model.

CARROLL E. IZARD
Department of Psychology, University of Delaware, Newark 19716

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I read with interest Zajonc's presentation of Waynbaum's physiological theory of emotion, according to which people smile, not because they are amused, but are amused because they smile. Zajonc points out that in some people the risorius muscle, which extends the angle of the mouth (and must therefore be exercised in smiling), is absent altogether. This raises the question of whether Waynbaum was one of those entirely lacking the risorius muscle or whether, alternatively, his risorius muscle was so well developed that he was prone to advance theories tongue in cheek. In either case, for the benefit of any reader of *Science* lacking the risorius muscle, I would like to point out that vigorous exercise of this particular bundle of contractile tissue, although apt to produce fatigue, is rarely amusing. On the other hand amusement in the absence of risorius muscle contraction, for example at Wodehouse's line that it is never difficult to tell the difference between a Scotsman with a grievance and a ray of sunshine, is difficult but not impossible.

This is not the only major weakness in Waynbaum's theory. According to Zajonc's account of it, the proof that people are amused because they smile is simple. Pull the corners of your mouth apart as if in intense exaggerated smile. After several seconds the frontal vein will be gorged with blood. Cerebral blood is thus momentarily retained causing intracerebral hyperemia, which in turn leads to a surge of subjectively felt positive affect. This is simple enough, but the timing is wrong. Some of us are a bit slow, but occasionally we get a joke in less than 2 seconds.

Another defect of Waynbaum's theory is that it fails to resolve the paradox that the intensity of emotion, as expressed in behavior, is inversely related to the intensity of associated visceral changes. For example, sociopaths notable for a lack of emotional affect are characterized by hypersensitivity to epinephrine and thus respond to emotionally evocative stimuli by abnormally large increases in heart rate and blood sugar level (*1*). Conversely, hyperemotional individuals tend to display abnormally slight endocrine and circulatory responses to emotion-arousing stimuli (*1*). These facts seem readily explained only by a feedback theory that links the bodily and conceptual components of emotion to one another as both cause and effect.

A. N. BURDETT
Research Branch, British Columbia Ministry of Forests, 4300 North Road, Victoria, Canada V8R 5J3

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Waynbaum published his vascular theory of emotional efference in 1906 (*1*). Modern developments in neurophysiology show him wrong on a number of counts, as I acknowledged in my article. The critics of the vascular theory hasten

to spell out some of the ways in which Waynbaum erred, or to put it more precisely, where he anticipated future knowledge incorrectly. But their criticisms are not always valid or relevant. For example, Burdett takes the vascular theory of emotional efference to task because "it fails to resolve the paradox that the intensity of emotion, as expressed in behavior, is inversely related to the intensity of associated visceral changes." However, his statement contradicts the general evidence which shows some, albeit low, positive correlation (*2*). And his own support for the contention is wanting because it selects the special case of the sociopath.

Fridlund and Gilbert, on the other hand, write that there is "little evidence that facial actions influence emotion." They thereby contradict Darwin's ideas (*3*), which they seek to promote. Darwin said it quite clearly: "The free expression by outward signs of an emotion intensifies it. On the other hand, the repression, as far as possible, of all outward signs softens our emotions" (*3*, p. 22). Moreover, in citing evidence for the assertion Fridlund and Gilbert conveniently note only those experiments that failed to support the hypothesis (*4, 5*), but omit the many more that supported it (*2, 6, 7*). One experiment they do cite in this context confounded motor action with the feeling state because the subjects were explicitly asked to look "afraid," "calm," or "neutral" (*5*). The other experiment (*4*), widely criticized (*8*), avoided such confounding, but required the subject to hold a facial expression steadily for 2 minutes—an interval much longer than that of a normal expression, which may produce peculiar subjective effects. In any event, these criticisms have limited value because it would have been nothing short of a miracle had Waynbaum anticipated correctly the future 80 years of knowledge.

The crucial question is whether Waynbaum was in principle right and whether his basic idea has merit. The critics allow the vascular theory to have some unspecified and highly qualified merit, but they, in particular Izard, are concerned that one might possibly take it as a serious challenge to Darwin's evolutionary theory of emotional expression. Thus, they try to show that Waynbaum's work leaves the validity of Darwin's ideas intact.

Darwin posed the important question of why different muscles are involved in the different emotions. But he never gave even a glimmer of an answer. Waynbaum's theory is nearer to supplying such an answer. I, therefore, consider the vascular theory to be a significant advance over the evolutionary theory of emotional expression, which—if it had provided a full explanation—should have contained conceptual elements to deal with the physiological antecedents of emotional efference. In reference to the latter theory, Fridlund and Gilbert offer as their main argument the assertion that "Whatever its original purpose . . . our exquisite facial repertoire now serves *primarily* (italics mine) a paralinguistic function." This assertion implies that the original purpose of those facial efferents, which at one time functioned exclusively to restore vascular equilibrium, has been supplanted by the new paralinguistic function. Yet nothing in the theory of evolution or in any other theory of emotional expression claims that a behavior will lose its original function if it acquires another, especially if the two functions are not incompatible. Such an argument is particularly bizarre if we consider that the original purpose of the behavior in question was to participate in safeguarding a vital physiological process (CBF homeostasis), whereas the social purpose that displaced it was less important. The explanation of emotional expression becomes quite problematic if it is to rest on one behavioral function to the exclusion of all others. The two purposes, vascular and paralinguistic, are not incompatible. A great loss would have been incurred if we had abandoned one of the means of maintaining the stability of CBF—a condition crucial for the maintenance of life—just because the behaviors in question acquired a paralinguistic role.

Consider hiccups, sneezing, vomiting, coughing, and yawning. Each of these actions appears to have as their primary purpose to protect the organism against a deficient process. They vary in their derived paralinguistic functions from nil (as in hiccupping) to occasional (as in yawning). One can readily conceive that any of these acts could acquire more extensive expressive significance, such as that attributed to smiling or frowning. Would they, as a consequence, lose their original purpose? There are no grounds whatever to believe that if vomiting were to symbolize disgust, for example, it would stop supplying gastric relief. If any of these five actions acquired additional symbolic significance, their morphology would remain universal across cultures and their original function would continue to be performed independently of their acquired meaning. In contrast, paralinguistic symbols that do not derive from restorative functions, such as the wink or the thumbed nose, vary from culture to culture.

Note that the paralinguistic function of emotional efferents is not unrelated to their physiologic function. Smiling communicates positive hedonic tone just because it is associated—often causally—with a true positive hedonic tone, subjectively experienced as such. And would yawning have come to communicate boredom if it had nothing to do with sleepiness?

Smiling and weeping would have been a part of "our exquisite facial repertoire" whether they were understood or not, and independently of their expressive quality. They exist because they "feel good" just as the pain and the effort grimace "feel good." The effort grimace, in fact, is an excellent case in point. Its purpose is seldom to impress bystanders with one's prowess or with task difficulty, for the effort grimace is made whether or not there are any onlookers. It performs mainly a regulatory support function by momentarily shunting arterial blood away from the brain by the action of several cervical muscles, and it arrests the draining of venous brain blood by the action of the corrugator and frontalis muscles. In fact, a lesser effort is exerted when one is not allowed to make an effort grimace (*9*). And "biting the bullet" or "grinning and bearing it" have been believed to be effective analgesics for centuries, although related experimental research (*7*) has not always agreed with these precepts.

The infant is capable of pain grimace at birth (and probably even before), and he (or she) is capable of sneezing, coughing, hiccupping, yawning, and vomiting. The infant is also capable of smiling very early after (and probably even before) birth, and the smile occurs independently of the social context, for it is not yet a responsive social smile, but a smile that, according to the vascular theory, makes a positive adjustment of the cerebral blood flow. Only later, after several weeks, does the child learn to respond to others with a smile, and what was at first an intrinsically satisfying regulatory function is now a social signal as well. The classical and the modern evolutionary theory must, above all, answer the question of whether the smile would have become an emotional efferent, universally produced and universally recognized, if it had no intrinsically satisfying consequences.

The vascular theory of emotional efference makes it clear that the evolutionary theory of emotional expression alone cannot furnish a full explanation of emo-

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tional motor action. It dramatizes also the fact that the evolutionary theory has not generated interesting new hypotheses about emotional expression or about the emotions, and in over one century has not led to much interesting research. In contrast, the vascular theory has generated a host of new interesting and testable hypotheses. Even if the basic theory is wrong in some respects, the hypotheses that can be derived from it are in themselves quite worthwhile.

The challenge of vascular theory of emotional efference to the evolutionary theory of emotional expression does not imply that the two are mutually contradictory. On the contrary, together they can form a richer explanatory basis for expressive behavior. The vascular theory of emotional efference supplies the evolutionary theory of emotional expression with an explanation of why and how certain emotional gestures came to be parts of the human communication system and why they are universal across cultures and often across species. How and to what extent emotional efferents serve a restorative vascular function is a problem for empirical research.

R. B. ZAJONC
Research Center for Group Dynamics, University of Michigan, Ann Arbor 48106

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Erratum: The "turritid gastropod" referred to on page 713 (column 2, line 22) of the article "Hydrothermal vent animals: Distribution and biology" by J. Frederick Grassle (23 Aug.) should have been a "turrid gastropod." The first reference 26 on page 716 (column 2, line 14) should have been to R. A. Lutz and D. C. Rhoads, *Eos* **64**, 1017 (1983). The statement at the end of page 716 that vent animals have metabolic rates that are orders of magnitude higher than relatives in other parts of the deep sea cannot be substantiated because, although many deep-sea organisms have low metabolic rates, benthic decapod crustacea and echinoderms from areas away from hydrothermal vents in the deep sea have metabolic rates similar to those of vent species when measured at the same temperature. This is further discussed in a forthcoming issue of the *Bulletin of the Biological Society of Washington.*

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