CURRENT ANTHROPOLOGY Vol. 19, No. 2, June 1978

Coca Chewing and High-Altitude Stress: Possible Effects of Coca Alkaloids on Erythropoiesis[1]

by Andrew Fuchs

INTRODUCTION

The shrub *Erythroxylon coca* is widely cultivated in the warm, moist valleys along the eastern slope of the Bolivian and Peruvian Andes between the altitudes of 300 m and 1,800 m (Rodriguez 1965:13). The plant, 1–4 m high, is covered with small, dark-green leaves which are chewed throughout the Andean highlands, chiefly by Aymara and Quechua Indians. The leaves are known to contain no less than 14 alkaloids of potential pharmacological importance (Martin 1970:422), of which the best-known is cocaine. Andean Indians chew coca leaves in conjunction with the alkaline ashes of various edible plants, which facilitates the extraction of these alkaloids.[2]

Consumption of the coca leaf in Bolivia and Peru has been continuous and extensive. Evidence exists for its use throughout the Andes well before the rise of the Inca empire (Rowe 1946:291). Earlier writers thought that use of the drug was limited to those Incas with religious and noble status (see Mortimer 1901:55–89; Mason 1957:142; Rowe 1946:292), but recent work suggests that coca use during this period was quite widespread (Golte 1970:479; Burchard 1976:385; Murra 1967:393). With Spanish rule, coca consumption appears to have increased throughout the Andean region, and modern coca use probably exceeds 10,000,000 kg yearly (Verzar 1955:364).

International concern over what was regarded as cocaine addiction on a mass scale prompted the establishment of a United Nations Commission of Enquiry, which interviewed Indian coca chewers to determine their personal motivations for using the drug. Typical responses to the Commission's queries included (1) coca assuages hunger and provides a substitute for food and water and (2) coca increases strength and energy, preventing fatigue and drowsiness during work (United Nations 1950:38; see also Tschopik 1951:157). More recent formal questionnaires have elicited similar responses from coca chewers (Burchard 1976:49; Fabrega and Manning 1972:250). Further reported motives for the use of the drug include (3) coca reduces the pain and dizziness associated with working at high altitudes (Monge 1948; Mortimer 1901:223–24) and (4) coca reduces the sensation of cold (Little 1970:236; Fabrega and Manning 1972:250).

The United Nations Commission deemphasized these motives, describing them (p. 53) as "superstition(s) due to the Indian's lack of education." The ability of coca to produce the stated effects has been documented, however, by researchers who either conducted physiological studies or chewed the leaves themselves, indicating that there is more to the phenomenon than the word "addiction" suggests. For example, as early as 1856, Clement Markham, a British doctor travelling in the Andes, wrote (p. 152): "I chewed coca, not constantly, but frequently . . . and besides the agreeable feeling it produced, I found that I could endure long abstinence of food with less inconvenience than I should otherwise have felt." This property of the drug and its suppression of the sensations of cold and thirst have also been discussed by Mortimer (1901:463–88) and Gutierrez Noriega (1947), among others. Hunger reduction may indeed be an especially important incentive for coca use, since hypoglycemia, a symptom of which is hunger, has now been documented for many of the Andean Indians who use the drug (Bolton 1973:253).

Moreover, the known personal motives for the use of the drug in the Andes differ from those documented among the illicit users of cocaine in the United States. Nail, Gunderson, and Kolb (1974), for example, interviewed United States Army recruits and found that those who took cocaine used it primarily for pleasure or to enhance other pleasurable activities, specifi-

[1] I would like to express my gratitude to Solomon H. Katz, Francis E. Johnston, Ruben E. Reina, Alta Jablow, Nancy Minugh, Trudy Van Houten, and Robert Baron for their comments and guidance during the composition of this article.

[2] For a more complete discussion of the preparation, taking, and paraphernalia surrounding the use of the drug, see Cooper (1949) or La Barre (1948:67–70).

ANDREW FUCHS is a doctoral candidate in the Department of Anthropology, University of Pennsylvania (University Museum, 33d and Spruce Streets F1, Philadelphia, Pa. 19104, U.S.A.) and a research associate in the Department of Biochemistry, School of Dental Medicine, University of Pennsylvania. Born in 1952, he was educated at Brooklyn College (B.A., 1973) and the University of Pennsylvania (M.A., 1976); he expects to be awarded the Ph.D. in 1979. He has been Instructor of Anatomy in the University's School of Medicine and School of Dental Medicine and Acting Director of the Department of Anthropology's Fossil Reproduction Casting Program. His research interests are human biology, anatomy, and paleonutrition, in particular the relationship of diet to the structural and chemical composition of bone and its application to paleonutritional research.

The present paper, submitted in final form 9 IX 77, was sent for comment to 50 scholars. The responses are printed below and are followed by a reply by the author.

TABLE 1

PREVALENCE AND INTERVAL OF COCA CHEWING IN PERSONS 20 YEARS AND OLDER (%) IN FOUR PERUVIAN VILLAGES

VILLAGE	INTERVAL						TOTAL	
	Daily		Weekly		Occasionally			
	Males	Females	Males	Females	Males	Females	Males	Females
San Antonio	0	0	2.8	2.5	0	0	2.8	2.5
Cachicoto	30.3	11.7	5.4	9.2	0	0.9	35.7	21.8
Yacango	11.0	0	13.6	2.8	21.8	7.6	45.4	10.4
Pusi	44.5	57.6	19.0	13.9	5.2	2.9	68.7	74.4

SOURCE: Buck, Sasaki, and Anderson (1968:99)

cally sex. No evidence of similar motivations for coca chewing exists today in the Andes,[3] where the drug's use appears to satisfy more pressing needs, namely, alleviating hunger, thirst, cold, and pain.

Finally, the documented behavioral effects of coca do not closely correspond to those reported in North American cocaine users. In a summary of their research conducted at the Haight-Ashbury Free Medical Clinic, Gay et al. (1975) report the effects of cocaine among their patients to be "euphoria, garrulousness, restlessness and excitement." Contrasted with this, most recent research among Andean Indians indicates that absolutely no behavioral changes can be observed as a result of coca chewing (Cárdenas 1952:9; Monge 1952:13; Hanna 1974:283). Moreover, chewers vigorously deny euphoric effects (Gutierrez Noriega 1947:146). This does not exclude the possibility of effects which are not perceived by those who chew coca habitually, but demonstration of such awaits further research. In any event, sufficient evidence has accumulated in recent years for most anthropologists familiar with coca chewing to conclude that it is not similar to cocaine use as practiced in North America.

Before the arrival of this new climate of opinion, Carlos Monge of the Peruvian Instituto Nacional de Biología Andina campaigned in the international forum against the popular view that coca chewing somehow contributed to the poor socioeconomic status of Andean Indians (see, for example, Gutierrez Noriega and Zapata Ortiz 1948). Monge (1948, 1952) argued that the leaf was, in some unknown manner, indispensable for long-term adaptation to the high altitudes where many Aymara and Quechua Indians live. The idea is especially attractive since many of the symptoms of chronic oxygen deficiency (hypoxia) are just those discomforts which coca chewers seek to alleviate in their use of the drug, namely, fatigue, pain, and possibly hunger.[4]

Since Monge's death, several biocultural explanations for coca chewing have been proposed by anthropologists (see Hanna 1971, 1974, 1977; Bolton 1973; Burchard 1976) as both theoretical constructs and pharmacological knowledge have developed. Even in this new context, however, the possibility that coca chewing may be beneficial to individuals suffering from long-term hypoxia exposure has not, as yet, been investigated.

In this article I will use the available ethnographic and physiological data to suggest the need for renewed attention to this possibility and will propose a mechanism by which coca chewing may indeed aid individuals who suffer from hypoxia-induced chronic mountain sickness.

[3] Martin (1970:433) suggests that the Incas may have used coca as an aphrodisiac, but the evidence is scant.

[4] Bolton (1973) has documented hypoglycemia among the Aymara-speaking Qolla, and there is some reason to believe that hypoxia has a disruptive influence on glucose metabolism (Chinn and Hannon 1969).

COCA AND ALTITUDE

In general, the proportion of Indians chewing coca increases with altitude. Monge (1952:14) noted this relationship, finding that coca use was "most widespread" at 15,000 ft. (4,572 m), well above the region where it is cultivated; "seldom encountered" at 8,000 ft. (2,436 m); and "an exception" at sea level. Further qualitative support is available (La Barre 1948:67; Saenz 1938), but quantified data are difficult to find.

Buck, Sasaki, and Anderson (1968) studied the epidemiology of coca use in four Peruvian communities: San Antonio, at 500 ft. (150 m), Cachicoto, at 2,400 ft. (720 m), Yacango, at 6,150 ft. (1,945 m), and Pusi, at 11,500 ft. (3,450 m). Data from their sample are presented in table 1. As can be seen, the relationship to altitude is not absolute in that a greater percentage of the inhabitants of Cachicoto chew coca than those in Yacango. The data are complicated, however, by the increased availability of coca in Cachicoto, which is in the coca cultivation zone. Even more significant, there had been a recent influx of Indian men into Cachicoto from higher altitudes at the time the study was undertaken, as well as an emigration of Indian men from Yacango (Buck, Sasaki, and Anderson 1968:4, 8).

The frequent migration of many Andean Indians makes interpretation difficult. Gutierrez Noriega (1944) points out that Aymara and Quechua Indians who come to work at low altitudes persist in chewing. Cabieses Molina (1946, quoted in Wolff 1950:152) reports, however, that when Andean natives move permanently to low altitudes, "a great majority . . . stop using the drug."[5]

There are several other exceptions to the relationship of increased coca use and high altitude which must be considered here. First, coca is known to have been used among the indigenous peoples of the East Andean Montaña. However, ethnographers who have studied the area point out that coca use there is limited (Métraux 1948:481; Steward and Métraux 1948:590). Moreover, the ethnographic evidence indicates that, where indigenous lowland peoples use coca, it is prepared in a strikingly different manner from that of the Andean population. Lowie (1948:44), for example, found that the Uapes "roast and pound the leaves, mix the powder with ash and suck out the powder." Similar preparations have been reported for these people (Goldman 1946:793), for the Witotoan tribes (Steward 1948:759), and for the Boro and Huito Indians (Pérez de Barradas 1940:324). Since the manner in which the leaves are prepared and taken is closely related to the physiological effects of coca (see below), the use of the drug by indigenous lowland peoples cannot be considered to be the same as the chewing of coca leaves in the highlands.

[5] While the migration of Quechua Indians from the highlands to the coastal city of Lima has received the attention of anthropologists in recent years (Mangin 1970*a*, *b*), no data regarding the persistency of coca chewing among these people are available.

A second notable exception to the correspondence between coca use and high altitude is that mestizos and Europeans rarely chew, even at the highest altitudes (Gutierrez Noriega and Zapata Ortiz 1948). The socioeconomic status of these people, generally higher than that of the Indians, might explain this phenomenon in view of the personal motives reported by Indians for the drug's use. In highland communities where class distinction is greatly emphasized (see, for example, Baker 1968; Nuñez del Prado 1973), however, mestizos may not chew because the use of coca is so closely associated with the lower status of Indians. In this light, Sáenz's comment on the matter deserves attention: "In some regions coca is used by all classes with the sole distinction that the lower classes reveal their addiction in public while the other classes are careful not to be seen" (Sáenz 1938, quoted in Wolff 1950:144). There can be no question, however, that most mestizos in highland communities do not use the drug.

The United Nations Commission (1950:55) did find, however, that mestizos chew coca where they work in mines. In fact, the dependency of mineworkers on the drug was perhaps the overwhelming reason for the drug's acceptance and eventual control by the colonial Spanish (Mortimer 1901:157). The United Nations Commission was told that miners refused to work unless they were supplied with coca.

A final exception to the relationship of coca use to altitude was reported by Zapata Ortiz (1952:31), who pointed out that the majority of Indian women do not chew coca. This observation is partially substantiated by Buck, Sasaki, and Anderson (1968:99), who found that men consistently chewed more than women except in Pusi, the highest of the four communities studied (table 1). Similarly, La Barre (1948:67), who studied Aymara communities on the Bolivian altiplano, generally above 3,600 m) noted that "all Aymara men and women" chew coca, and Tschopik (1951:157), also among the highland Aymara, found that "old and young, men and women" use coca. At a slightly lower altitude, however, between 2,020 m (6,630 ft.) and 2,890 m (9,470 ft.), Hernández de Alba (1946:952) found that coca was used widely by men but very little by women, despite the absence of cultural proscriptions against its use.[6] The United Nations Commission (1950:53) also reported that, below the very highest inhabited altitudes, women generally chew less than men.

The data on sex differences and coca chewing may be interpreted as an extension of the relationship between coca consumption and increased altitude. Like men, women at higher altitudes chew more than their counterparts at lower altitudes, although proportionately fewer women seem to chew than men, except at the very highest altitudes, where everyone may chew.

In summary, the relationship between coca chewing and high altitude has a number of significant exceptions. Some of these, among them the use of coca by the indigenous peoples of the lowlands, can be eliminated by more clearly defining the phenomenon under consideration. Others, among them the high consumption of the drug in the mines and the difference in consumption by sex, remain to be explained by any complete hypothesis regarding the efficacy of chewing and will therefore be further considered in this paper.

COCA AND COLD STRESS

In recent years many researchers have explored the possibility that substances derived from coca leaves may be somehow beneficial to those who chew. Stoner and Little (1969), working with rats, suggested that, in acting as a peripheral vasoconstrictor, cocaine may conceivably decrease heat loss, thereby acting beneficially during cold stress. Together with the recognition that cold is, at times, a significant stress for highland Andean natives, this suggestion has guided the bulk of physical anthropological research into coca chewing.

Little (1970), for example, measured the effect of coca chewing on skin temperatures for Quechua subjects in Nuñoa, Peru, but obtained no statistically meaningful results. However, when Hanna (1971) conducted a series of controlled experiments designed to determine the physiological benefits that may accrue from chewing coca while working in a cold environment, he found that coca use during cold exposure produced a small degree of vasoconstriction observed as lowered temperature in the extremities. Concluding that there was reduced heat loss from these areas, Hanna suggested that coca may indeed be beneficial in cold environments in that it may aid in thermoregulation. Apart from the use of different statistical procedures, Hanna's use of working subjects may account for the discrepancy between his and Little's conclusions, since there is evidence (Peterson and Hardinge 1967) that the physiological effectiveness of cocaine is significantly increased during exercise.

Stoner and Little's suggestion has been supported by Hanna's research in the field. Certain questions remain unanswered by the cold-stress hypothesis, however, suggesting that some other process is also at work.

First, the frequency of coca use does not correlate as closely with climate as one might expect if cold stress were the only important consideration. While Little (1970:236) observed that 75% of coca chewers interviewed indicated that they chewed more often in rainy or cold weather, this still means that a substantial amount of coca is chewed during warm weather, especially if one considers that the rainy season on the altiplano is the warmest part of the year (La Barre 1948:13). Furthermore, because of its tropical latitude but high altitude, the altiplano may be warm during the day, in the region of 60° F., and below freezing at night.[7] Still unanswered, then, is why coca is predominantly chewed during the daytime work hours rather than at night (Gutierrez Noriega 1948; Mishkin 1946:418; Stein 1961:169; Tschopik 1946:884). Also unexplained is why mineworkers use coca extensively, since mines are as often hot as they are cold (Galeano 1973:52). Finally, the cold-stress hypothesis does not explain why, except at the highest altitudes, men consistently chew more than women and children, all of whom are presumably equally subject to cold stress. In fact, Quechua women may be subject to even more cold stress than Quechua men on the altiplano (Baker 1968:20).

POLYCYTHEMIA AND COCA CHEWING

An analysis of the available physiological literature indicates that coca chewing may be beneficial in mitigating the effects of hypoxia. The explanation of coca's beneficial properties here proposed involves a complex set of interrelationships between (*a*) a well-known high-altitude adaptive mechanism, polycythemia (abnormal increase in the number of red blood cells), (*b*) the strain on this mechanism culminating in chronic mountain sickness, and (*c*) the effects of continuous exposure to the alkaloids contained in coca.

That polycythemia is a standard response to the hypoxia of high altitudes has been known since Hurtado's (1932) classic study. In it, he reported that red blood cell counts in 132 high-

[6] This is not to say that the amount of leaves an individual may chew is not socially influenced. Burchard (1976:85) found that those Indians who chewed too much or not at all were disdained by their fellows in the community he studied in the department of Huánuco, Peru. However, I know of no reports from the Andean highlands to the effect that women, for example, are forbidden to chew the leaf.

[7] For a complete description of the weather on the altiplano, see Baker (1968:37–44).

altitude-dwelling Indian men were, on the average, a million higher per cubic centimeter than those of sea-level-dwelling natives. He also found that blood viscosity in high-altitude-dwellers was concomitantly increased, although plasma and serum levels remained within normal limits. Until recently, it has been generally assumed that increases in the red blood cell counts of high-altitude-dwellers were advantageous in that more hemoglobin was available to deliver oxygen to tissues.

As knowledge of high-altitude physiology has increased, more emphasis has been placed on the detrimental effects of polycythemia which result from increased blood viscosity. Viscous blood is difficult to pump and tends to sludge in capillaries. In their study of blood viscosity, Struima and Phillips (1963) report that clinical manifestations of disease can be expected at a relative viscosity of more than five centostokes and are invariably present at seven centostokes and more. Hurtado originally reported blood viscosity in high-altitude native males as averaging from six to ten centostokes, ranging from five to an incredible fifteen. Hence, there can be no question that polycythemia represents a significant stress for Indians who dwell at high altitudes. Garruto (1973), in his study of Quechua Indians, concluded that red blood cell counts in many males were pathological rather than beneficial, and Mazess (1970) reached a similar conclusion in his extensive review of the available data and literature on circulatory adjustments to high altitude. Additional support for this view comes from Monge's (1966:65) observation that anemias are well tolerated in high-altitude-dwellers. This would be difficult to explain if polycythemia were a necessary adjustment to altitude.

The two most common clinically reported manifestations of polycythemia are fatigue and headache (Weinreb and Shih 1975). These symptoms closely match those reported for chronic mountain sickness (Monge 1943:175; La Barre 1948: 49–50) and are also symptoms which coca chewers seek to alleviate in using the drug.

Furthermore, a strong relationship between coca chewing and chronic polycythemia exists in that those individuals who chew the greatest amounts of coca are those who could be expected to endure the greatest polycythemic stress. For one thing, males are more susceptible to polycythemia than females. The evidence indicates that androgens act to increase production of erythropoietin, the hormone responsible for the production of red blood cells, while estrogens tend to suppress its production. Working with rats, Krantz and Jacobson (1970) showed that castrated males had decreased red blood cell production relative to normal males, while ovariectomized females had increased red blood cell production relative to normal females. In humans, oxymethalone (an androgenic steroid) has been so well demonstrated to stimulate erythropoiesis that it is used in the treatment of anemias. Indeed, some patients have responded so well to oxymethalone treatment as to become ill with polycythemia (Low-Beer and Scott 1976). Fried, Gurney, and Fesler (1971) concluded from their laboratory work that androgens act to increase red cell production at any given level of hypoxic stimulation.

Thus, it can be expected that men, with an active output of androgens, would tend to be subject to polycythemic stress at altitudes at which women, with an active output of estrogens, would not be. At the highest altitudes, however, where hypoxia is most severe, women would be expected to endure considerable polycythemia as well. This appears to correspond to the pattern of coca chewing discussed above. In this light, it is also interesting to note that males tend to start chewing as they enter puberty (Little 1970:236; Zapata Ortiz 1952:27). Furthermore, elderly women, presumably no longer maintaining high levels of estrogen, are found to chew at altitudes where young and middle-aged women do not (United Nations 1950:53).

Polycythemia is also a severe problem in miners, regardless of the altitude of the mines in which they work (Monge and Monge 1966). Apart from considerations of the amount of oxygen available in mines, miners are frequently afflicted with silicosis, a disease which damages lung tissue to such an extent that blood oxygenation is inhibited. The response to this anoxic condition in the bloodstream is severe polycythemia similar to that induced by breathing air poor in oxygen.

While polycythemia is a significant stress for mestizos and Europeans who live in the high Andes as well, these individuals, because of their higher economic status, generally have access to medical treatment (Baker 1968:8), which may include phlebotomy (see Rakita, Gillespie, and Sansetta 1965).[8]

The foregoing suggests that the pattern of coca chewing is coincident not so much with either cold or high altitudes per se, but with extreme polycythemic stress among individuals with no medical recourse. This, along with the assertions of many chewers that the use of the leaves alleviates the symptoms of chronic mountain sickness, may be considered an indicator that the coca alkaloids are somehow specific for the disease. Furthermore, the pattern of coca consumption during work is itself suggestive, since high-altitude stress may be considerably aggravated by exercise.

Given the nature of severe polycythemia, any substance or behavior which, barring deleterious side effects, causes a reduction in red blood cell levels (measured as hematocrit values) would be helpful in reducing the symptoms of the stress. It is likely that the alkaloids entering the bloodstream of those who chew have just such an effect.

THE COCA ALKALOIDS

Understanding the effects of coca depends on appreciation of the quantity of leaves consumed and the manner in which they are ingested. Many researchers have estimated the daily coca-leaf consumption of highland Indian chewers (Ciuffardi 1949; Gutierrez Noriega and Zapata Ortiz 1948; Ashley 1975:15; Baker and Mazess 1963:1466; Burchard 1976:84). The most careful work appears to be that of Hanna (1974:284), who, in a controlled experiment, found that in Nuñoa, Peru, a community at an altitude of more than 4,000 m, the mean daily consumption was 58 g per adult, with men chewing slightly more than women. The United Nations Commission found similar daily consumption among workers at the Cananiri Mine in the Catavi region, where 125 g was considered to be a two-day supply (United Nations 1950:21).

Ciuffardi (1949) reported that, with a 34-g *cocada*, or quid, an average of 178 mg of alkaloids was ingested, of which 80% was cocaine. Using these data, Hanna (1974:284) estimated that 250 mg of cocaine were available to his subjects daily. However, research by Montesinos (1965) indicates that much of the cocaine present in the leaves may undergo hydrolysis in the gastrointestinal tract before entering the bloodstream of coca chewers. Furthermore, he argues that the principal hydrolysis product of cocaine, ecgonine, may be considerably more important than the parent compound in producing physiological effects in chewers. Burchard (1976:149–50) elaborates this point, arguing that the differences between the two chemicals may account for the absence of euphoric effects in those who chew the leaves. Since some juice from the *cocada* is swallowed, at least some cocaine undoubtedly is transformed in the manner these authors suggest. These authors may underestimate the amount of alkaloids ingested directly by the oral mucosa. Since cocaine is easily absorbed by all mucous membranes (Ritchie and Cohen 1975:387), and since the alkaline ash with which the leaves are chewed inhibits hydrolysis in the mouth (Verzar 1955:365), it is still likely that quantities of cocaine enter the

[8] Garruto (1973:163) found that mestizos have considerably higher hematocrits than Quechua Indians in Nuñoa. If the ideas put forth in the course of this paper are correct, the fact that mestizos do *not* chew coca may account for this phenomenon.

bloodstream of coca chewers, although the amount is now uncertain.

The foregoing suggests that the pharmacological effects which can be expected to result from coca use cannot be divorced from the manner in which the leaves are ingested. For example, by powdering the leaves, mixing them with ash, and using the mixture as snuff, the indigenous peoples of the lowlands appear to be maximizing the amount of cocaine available from the leaves and delivering it to the bloodstream in the quickest possible manner.[9] In contrast, both cocaine and ecgonine would be expected to enter the bloodstream of highland coca chewers, and the dosage of the two chemicals appears to be spread out over the course of an entire day. The pattern of coca chewing during a typical Quechua work day has been described by Mishkin (1946:418):

A Quechua work day at plowing time (*Barbecho*) begins at dawn, when the man of the household goes to his plot to meet the members of his work party (*masa*). These have been notified a few days previously to appear. Then, seated on the ground, the party chews some coca supplied by the owner of the plot. Actual work with the *chaquitaclla* begins a little later and is interrupted after an hour for another coca chew. Work is then resumed and continues without interruption until noon. Lunch usually consists of chuñu, potatoes, and sometimes, cheese. The end of the meal is a signal for more coca. At about two o'clock, after another hour of work, the party stops to partake of the host's coca. The work day ends at about five o'clock, when the members of the work party return to their homes.

This pattern is typical of coca use throughout the highlands and, along with Ciuffardi's (1949) observation that at least 43% of the alkaloids ingested by chewers was not destroyed or immediately excreted by the body, makes it likely that coca chewers have significant quantities of both cocaine and ecgonine continuously present in their bloodstreams.

It remains to be shown how long-term exposure to these chemicals would influence red blood cell production (erythropoiesis) in a manner that would be helpful in alleviating polycythemic stress. To this end, a short discussion of the mechanisms of erythropoiesis follows.

ERYTHROPOIESIS AND THE COCA ALKALOIDS

A renal erythropoietic factor (REF or erythrogenin) exists which, while elaborated in the kidney, is not in itself capable of stimulating red blood cell production (Erslev, Kazal, and Miller 1971). REF is apparently activated by a plasma factor. While increases in the plasma factor do not stimulate erythropoiesis, increases in REF apparently do. Fisher, Samuels, and Langston (1968) point out that the kidney has a microcirculatory system which makes it "particularly sensitive" to changes in oxygen tension. Thus, agents which either raise the oxygen demand or decrease the oxygen supply to the kidney are those which will increase REF production and consequently increase red blood cell levels. Conversely, those agents which lower oxygen demand or raise oxygen supply to the kidney decrease REF production. This may be the manner in which androgens, estrogens, and exercise exert their effects on red cell levels.[10]

Until the beginning of the last decade it was thought that localized oxygen tensions in the kidney exclusively determined erythropoiesis. Recently, the posterior hypothalamus has been demonstrated also to play a regulatory role (Halverson 1964, Takaku 1961, Medado, Izak, and Feldman 1967).[11] Although the exact mechanism of hypothalamic regulation of red blood cell levels remains unknown, studies have shown that small doses of atropine, having a strictly antimuscarinic effect (competing with the parasympathetic nervous system transmitter acetylcholine) on the posterior hypothalamus, decrease REF output by the kidney and consequently decrease red blood cell levels (Paulo, Roh, and Fisher 1971, 1972).

Atropine, ecgonine, and cocaine are strikingly similar chemicals (Cutting 1972, Grollman and Grollman 1970). This does not imply that they have identical properties; for example, of the three, cocaine alone has properties as a local anesthetic and the capacity to stimulate the sympathetic nervous system by potentiating norepinephrine. However, the effects of all three on the central nervous system are comparable (Grollman and Grollman 1970:405). Because of their tropine-like configurations, all are antimuscarinic (Cutting 1972). Both cocaine and atropine are pyrogenic—both first stimulate, then depress the central nervous system. The even greater similarities in the physiological effects of atropine and ecgonine have recently been catalogued by Burchard (1976:156–77; see also Goodman and Gillman 1970:375).

It follows that the antimuscarinic substances entering the bloodstream of coca chewers may depress erythropoiesis by depressing the critical areas of the posterior hypothalamus. Some evidence exists for this in coca chewers' assertions that the sensations of hunger and thirst are dulled, since the hypothalamic region of the brain is responsible for the regulation of these sensations (Anand and Brobeck 1951) as well as for the regulation of body temperature. It is therefore likely that substances derived from chewing coca do have an effect upon the cells of this organ (Verzar 1955:372).

Also, a body of empirical data exists which strongly indicates that coca chewers have lower red blood cell counts (hematocrit values) as well. In their epidemiological studies of four Peruvian communities, Buck and his colleagues (Buck, Sasaki, and Anderson 1968; Buck et al. 1968, 1970), collected valuable data on coca chewing, hematology, hookworm infestation, personal hygiene, and nutrition. Their data are sufficiently interesting that they require close examination here.

These researchers chose Cachicoto (see above) for a detailed study of the effects of coca chewing, since large numbers of chewers and nonchewers were available. They constructed 53 pairs, each composed of a regular coca chewer and a control subject matched for age, sex, occupation, and ethnic group. One of the most significant differences they found between pairs was that of hemoglobin and hematocrit values (table 2, fig. 1). The findings, that coca chewers had lower red blood cell levels than controls, might well be expected if coca chewers either were more poorly nourished or had more hookworm infestation than controls. To control for this, the researchers measured the difference between chewers and nonchewers matched for weight/height index and for hookworm load (tables 3 and 4). Coca

[9] This method of coca use would appear to be more analogous to that of cocaine users in the United States. It may be no accident that many of the lowland peoples who snort powdered coca leaves also use hallucinogens, for example, *cayapi*, while the use of *cayapi* is not reported for the highlands.

[10] There is a distinct possibility that cocaine may act to raise the oxygen supply to the kidney (thereby decreasing REF production) by potentiating norepinephrine at androneurergic receptors of effector organs. While it is well known that norepinephrine is a sympathetic nervous system transmitter and a vasoconstrictor at organ sites, Fisher, Samuels, and Langston (1968) found that intravenous infusion of low doses of norepinephrine caused an *increase* in renal blood flow, glomerular filtration rate, and urine output, while higher doses had the better-known effect. It is apparent that specific research at kidney sites needs to be conducted to determine the degree of norepinephrine potentiated at the dosages of cocaine and ecgonine liberated in coca chewing and the specific effect of this on renal blood flow.

[11] Evidence for hypothalamic regulation comes from the demonstration that lesions on the posterior hypothalamus cause a reduction in REF production (Halverson 1964). Takaku (1961) found that bilateral section of the splanchnic nerve abolished a decrease of renal blood or hypoxia. Medado, Izak, and Feldman (1967) induced a considerable rise in reticulocyte count by stimulation of the posterior hypothalamus and could not produce that effect with stimulation of the caudate nucleus, hippocampus, or cerebellum.

TABLE 2

Comparison of Coca Chewers and Controls on Selected Indices

Characteristic	No. Matched Pairs	Mean Difference Between Coca Chewers and Controls	Standard Error	P
Hemoglobin......	50	−2.31 g per cent	4.90	0.01
Hematocrit......	47	−7.2 % of packed cells	4.74	0.01
Total serum protein...........	36	−0.35 g per cent	1.86	0.07
Serum albumin...	36	−0.28 g per cent	1.87	0.07
Serum cholesterol.	36	−19.8 mg per cent	3.05	0.01

Source: Buck, Sasaki, and Anderson (1968:100)

chewers were characterized by lower hematocrit values in every weight/height category and at every level of hookworm load.

Since iron or vitamin deficiency could account for this relationship, it may be noted here that chewers have sources of iron and vitamins not available to nonchewers. The United States Federal Security Service of the Food and Drug Administration found that coca leaves contain significant amounts of vitamins B1, B2, and C (United Nations 1950:94). Cruz and Gullén (1948) found iron in the ashes of the edible plants with which coca is chewed, and Baker and Mazess (1963:1466) report iron in *cha'qo*, a clay substance which is common in the highland Peruvian diet.

It is not my purpose here to show that coca chewers are not malnourished, although there is some evidence in this regard (Baker and Mazess 1963, Mazess and Baker 1964). Buck's group did find, for example, that in general coca chewers had significantly lower serum albumin levels than controls (table 2), indicating possible protein deficiency. However, for the specific hematocrit data under discussion, the statistical relationship to coca use was stronger. The rigorous controls for ethnic affiliation, occupation, weight/height index, and hookworm infestation in these studies appear to indicate that coca chewing has an effect on hematocrit values beyond that which could be expected from nutritional considerations.

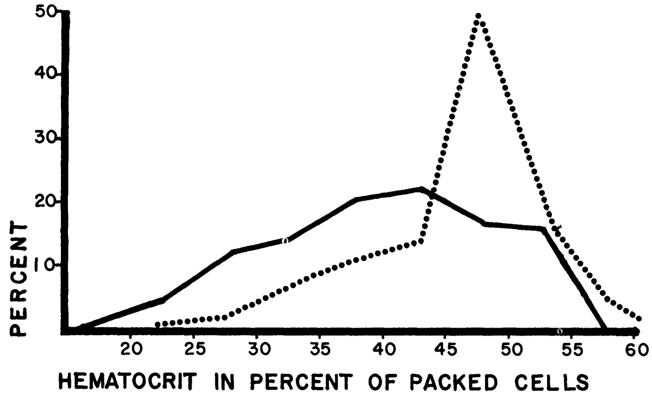

Fig. 1. Frequency distribution of hematocrit values in 46 coca chewers and matched controls (Buck et al. 1968:171), showing that a higher percentage of coca chewers (solid line) has low red blood cell levels relative to controls (dotted line).

CONCLUSION

Indian coca chewers in the Andes cite a variety of reasons for their use of the drug. These include alleviating symptoms of hunger, thirst, fatigue, cold, and pain. These stated motivations are in sharp contrast with those expressed by cocaine users in the United States, for whom the conditions of life are considerably better, suggesting that popular interpretations of coca chewing which ignore the expressed motivations of the users and regard chewing as merely "an addiction," "a habit," or even a pleasurable activity are mistaken, or at least too simple.

Despite the increased attention physical anthropologists have given to the effects of coca chewing in recent years, the pos-

TABLE 3

Intensity of Hookworm Infestation and Hemoglobin Mean Values in 41 Pairs of Coca Chewers and Controls

Hookworm Eggs	Coca Chewers No.	Coca Chewers %	Coca Chewers Mean Hb (g per cent)	Controls No.	Controls %	Controls Mean Hb (g per cent)	Difference (g per cent)
Negative...................	11	26.8	10.6	17	41.5	12.4	1.8
Few.......................	13	31.7	11.1	14	34.1	12.6	1.5
Moderate..................	15	36.6	9.6	7	17.1	11.2	1.6
Numerous..................	2	4.9	7.7	3	7.3	10.8	3.1
Total....................	41	100.0	10.4	41	100.0	12.2	1.8

Source: Buck et al. (1968:30)

TABLE 4

Mean Hemoglobin and Hematocrit Values by Weight/Height Index in Coca Chewers and Controls

Weight (lb.) / Height (cm)	Coca Chewers No.	Coca Chewers Mean Hb (g per cent)	Coca Chewers Mean Hematocrit (% of packed cells)	Controls No.	Controls Mean Hb (g per cent)	Controls Mean Hematocrit (% of packed cells)
0.55–0.67........	18	7.9	32.3	7	11.0	43.2
0.68–0.74........	15	11.3	40.3	13	12.0	43.7
0.75+...........	17	10.8	41.4	32	12.0	46.4

Source: Buck, Sasaki, and Anderson (1968:102) sibility of a relationship with high-altitude hypoxia stress has been neglected. Indeed, the available epidemiological data regarding coca use are so few and difficult to interpret that the association of coca chewing and high-altitude stress is easily obscured. Reinterpreted, however, these data do indicate that, where there are exceptions to a strict altitude/coca-chewing correspondence, they are better accommodated by an explanation which also emphasizes polycythemic stress rather than either cold or hypoxia alone. In the proposed physical mechanism associated with coca chewing, the antimuscarinic ingredients in the leaf act upon critical areas of the posterior hypothalamus to depress erythropoiesis. By so doing, they are antagonists to the hypoxia which stimulates excessive red blood cell production.

One strength of this explanation is that some of the symptoms of chronic polycythemia are identical to those conditions which chewers seek to alleviate by their use of coca, e.g., fatigue and pain. Further support is derived from the existence of data which indicate that, when nutrition and disease are taken into account as influencing factors, coca chewers present lower red blood cell levels than matched controls.

Clearly, more research regarding the effect of long-term coca chewing on erythropoiesis is needed. The ideas put forth in this paper will not be considered proven until more specific data are generated both in the laboratory and in the field. Nevertheless, the available physiological and ethnographic data appear to point to the same conclusion—that coca provides specific pharmacological relief for chronic polycythemia.

Comments

by RODERICK E. BURCHARD

Department of Anthropology, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2. 18 XII 77

Fuchs's article is a valuable contribution to the literature on coca use in general and the problem of its use and peasant health in particular. While I agree with most of what is said, there are several points that require critical comment.

First, because of the biotransformation of cocaine into ecgonine, not to mention the presence of cocaine-free ecgonine in the leaf itself, Fuchs is certainly correct in his observation that ecgonine "may be considerably more important than the parent compound in producing physiological effects in chewers." He is incorrect, however, in asserting that, "since the alkaline ash with which the leaves are chewed inhibits hydrolysis in the mouth, . . . it is . . . likely that quantities of cocaine enter the bloodstream of coca chewers" via the oral mucosa and that researchers such as Montesinos (1965) and myself (Burchard 1976) who place emphasis on ecgonine rather than cocaine "may underestimate" the amount of cocaine absorbed in this manner. On the contrary, Montesinos (1965:14–15) has shown that the hydrolysis of cocaine into ecgonine begins in the mouth, precisely because of "the action of the alkaline substance added to the leaf," and this same degradation of cocaine into ecgonine in the presence of alkaline substances has been demonstrated by Nieschultz and Schmersahl (1969) and by Vitti, Burchard, and Roscoe (n.d.). Moreover, even if trace amounts of cocaine escape destruction in either the mouth, the gastrointestinal tract, the liver, or the bloodstream, this does not preclude placing emphasis on ecgonine rather than cocaine in trying to explain the physiological effects of coca use. For example, in comparison to the rather weak atropine-like or antimuscarinic effects of trace amounts of cocaine, as Fuchs himself notes, I have pointed out "the even greater similarities in the physiological effects of atropine and ecgonine." Further, the rather weak antimuscarinic effects of trace amounts of cocaine are potentiated in the presence of larger amounts of ecgonine (Lévy and Zissmann 1950). Why perpetuate the cocaine syndrome of coca use when emphasis on ecgonine seems more justified?

Secondly, Fuchs's claim that Hanna (1971, 1974), Bolton (1973), and I (Burchard 1976) have overlooked Monge's (1946, 1952) hypothesized "direct relationship" between coca use and altitude or "the possibility that coca chewing may be beneficial to individuals suffering from long-term hypoxia exposure" is unjustified. All three of us have given more than passing attention to hypoxic stress, not to mention climatic, nutritional, and work stress, in our respective positions on coca use in the Andes. Moreover, following up on Bolton's (1973) suggestion that there may be widespread carbohydrate metabolism problems among Andean peasants living at high altitude and a relationship between these problems and the use of coca leaf, I have argued (Burchard 1975*a*, 1976, 1977) that, precisely because such antimuscarinic drugs as atropine are recommended for the management of such problems (Gray 1973, Miller and Keane 1972, Williams 1968), the antimuscarinic effects of coca chewing may offer Andean peasants significant medical benefits.

Finally, Fuchs's statement that "since the manner in which the leaves are prepared and taken is closely related to the physiological effects of coca . . . , the use of the drug by indigenous lowland peoples cannot be the same as the chewing of coca leaves in the highlands" is misleading. On the contrary, as I have pointed out in some detail elsewhere (Burchard 1977), with the exception of the "snorting" of powdered coca leaf through the nasal passage, coca use among Amazonian lowland peoples is not strikingly different from that among Andean highland peoples. Furthermore, granting that the same biotransformational and physiological processes take place in the organism of an Amazonian lowlander who ingests a combination of powdered coca leaves and an alkaline substance through the mouth as in the organism of an Andean highlander who ingests a combination of whole coca leaves and an alkaline substance through the mouth, then I think one can in fact compare its use in the two areas.

For example, just as the chewing of coca leaf in the Andes is more often than not accompanied by the ingestion of high-carbohydrate food substances (see Burchard 1975*a*:477–79; 1976:258–302), the ingestion of powdered coca leaf and an alkaline substance by such peoples as the Cubeo in the Amazonian lowlands is generally accompanied by the ingestion of manioc beer and other food substances (see Goldman 1948, 1963; Salser 1970; Weil 1975). Even more significantly, Prance (1972:229) writes of the use of a combination of powdered coca leaf and burnt banana-leaf ash by the Makú in lowland Brazil: "The powder is mixed with cassava, either with farinha flour or tapioca flour. This powder from coca forms a part of the daily diet of the Makús, and they prepare it fresh every evening."

Of course, in their efforts to explain the use of coca leaf by the Cubeo and the Makú, all the above-mentioned researchers place emphasis on the fact that coca leaf is the source of cocaine and consequently its use "deadens hunger pains." This same thing, of course, has also been characteristic of explanations of coca use at high altitudes. However, in view of the significant antimuscarinic effects of ecgonine (or, for that matter, of trace amounts of cocaine in the presence of larger amounts of ecgonine) and the fact that antimuscarinic drugs have been recommended for the control of carbohydrate malabsorption, it seems possible that coca use in the Amazonian lowlands may, as I have argued for the Andes, provide peasants with significant medical protection against problems of carbohydrate metabolism (Burchard 1977).

In summary, while I consider Fuchs's ideas concerning the relationship between coca use and polycythemia valuable, I believe the question of coca use is far more complex than he suggests. However, his argument has made me realize that it is far more complex than I had thought it to be also.

by C. C. CURTAIN
12 Esplanade, Williamstown, Victoria 3016, Australia. 4 XII 77

Fuchs's hypothesis is one of several attempts to establish a biological basis for coca chewing in the Andes. Bolton (1972, 1976), for example, has suggested that coca chewing contributes substantially to glucose homeostasis. Unfortunately, these hypotheses, like many other attempts to interpret cultural responses in terms of biological pressures, are confounded by population variability and the difficulty of studying all the factors involved in a single research program. For example, high-altitude polycythemia is by no means a constant trait in Andean populations. Moulin (1971), Salguero-Silva (1971, cited by Garruto 1976), and Garruto (1976) observed only a 10–12% increase in mean hematocrit and hemoglobin level in adult males living at high altitudes compared with those living at sea level. It is possible, but by no means probable, that these populations might have reduced their erythrocyte counts by chewing coca.

Another problem is the determination of the actual amount of coca alkaloids absorbed by the chewers. Lacking this knowledge, most of the studies on coca chewing rise little above the anecdotal. In this connection it should be noted that recent developments in radioimmunoassay permit the measurement of 5–10 nanograms of benzoylecgonine, the major metabolite of cocaine (Kaul, Millian, and Davidow 1976). This is the most sensitive technique available for monitoring cocaine ingestion by man, and it would be worthwhile investigating it as a means of estimating the amount of cocaine absorbed by coca-chewing subjects. Only then could meaningful correlations be made between coca consumption and hematocrit, glucose tolerance, or any other physiological parameter suspected of being associated with high-altitude stress.

by PAULO ROBERTO DE AZEREDO
Departamento de Antropologia, Universidade Federal do Rio de Janeiro, Largo de S. Francisco 1, 3º And., Rio de Janeiro 20.000, R.J., Brazil. 1 XII 77

Nem sempre um trabalho científico, fundamentado exclusivamente em fontes secundárias—em dados de segunda mão—, é meritório. Isso porque a pesquisa original, quando conduzida com propriedade e rigor metodológico, constitui-se em etapa imprescindível a permear a formulação e comprovação de uma hipótese de trabalho. Este, creio, não é o caso do presente artigo de Fuchs principalmente porque a bibliografia por ele compulsada, de boa qualidade, foi *habilmente* manipulada, permitindo-lhe chegar, sem maiores embaraços, à formulação da possibilidade de interrelacionamento entre o hábito de se mascar coca nos altiplanos andinos e o fenômeno da eritropoiese. O modelo proposto por Fuchs para explicar o contexto onde opera realmente satisfaz, em que pese a precariedade dos dados de apoio disponíveis presentemente.

Cumpre notar que, diante de proposições desta natureza, é necessária a devida prudência até que evidências abonadoras tenham sido acumuladas, seja a nível quantitativo, seja a nível qualitativo. Mas é o próprio autor que se incumbe de acentuar tal advertência, ao afirmar que, a despeito do registro fisiológico e etnográfico à mão parecerem reforçar a hipótese por ele sugerida, suas idéias somente poderão legitimar-se a longo prazo, à custa de novas pesquisas desenvolvidas tanto no campo quanto em laboratório.

Nada nos impede porém de, *mutatis mutandis*, entrever similaridades entre o artigo de Fuchs e os escritos de Allison sobre o traço siclêmico, na primeira metade dos anos cinquenta.

[A scientific study based exclusively on secondary sources—secondhand information—is not always praiseworthy. This is because an original study, when conducted with accuracy and methodological rigor, constitutes an indispensable stage of formulating and substantiating a working hypothesis. The present article by Fuchs is an exception, however, mainly because the bibliography consulted, of good quality, has been *skillfully* manipulated so as to permit him, without major difficulties, to formulate the possibility of an interrelationship between the habit of coca chewing in the Andean altiplano and the phenomenon of erythropoiesis. The model proposed by Fuchs to explain the context in which it operates is quite satisfactory, although the scarcity of the currently available supporting data must be taken into account.

It should be noted that, with propositions of this nature, due prudence is necessary until supporting evidence has been accumulated at both quantitative and qualitative levels. However, the author takes upon himself the task of emphasizing such a warning in stating that, in spite of the fact that the physiological and ethnographic records at hand appear to reinforce the hypothesis he suggests, his ideas can only be proven in the long term, through new research carried out in the field as well as in the laboratory. Nothing prevents us, however, from, *mutatis mutandis*, catching glimpses of similarities between Fuchs's article and Allison's writings on the sickle-cell trait in the early '50s.]

by A. ROBERTO FRISANCHO
Center for Human Growth and Development, University of Michigan, 1111 E. Catherine, Ann Arbor, Mich. 48104, U.S.A. 14 XI 77

This hypothesis is not supported by the data on which it is based. First, as indicated by the author, the Peruvian community of Cachicoto is situated at only 720 m (2,400 ft.), which by any criterion is well below the level at which altitude has a hypoxic effect on the organism (Baker and Little 1976, Frisancho 1976, Heath and Williams 1977, Ward 1975). Indeed, in comparative human physiology altitudes below 1,000 m are considered low. Therefore, the observed differences between coca chewers and nonchewers in Cachicoto cannot be related to the hypopolycythemic effects of coca, because the conditions conducive to polycythemia are not present in the first place. Second, polycythemia has clinical effects on cardiovascular functions only when the hematocrit levels are above 70% (Monge 1966, Ward 1975, Heath and Williams 1977). As indicated in figure 1, none of the nonchewers attained polycythemic levels. In other words, the absence of coca chewing is not associated with clinical polycythemia. Thus, the conclusion that coca provides medicinal relief for chronic polycythemia is not appropriate.

In summary, this is an interesting hypothesis, but its applicability is not supported by factual information and research in altitude physiology, Paradoxically, the strength of this paper is not the hypothesis that it postulates, but the clarification of the antimuscarinic ingredients and depressant effects of coca leaves, which will be useful in understanding the effects of coca chewing on the central nervous system.

by JOSEPH A. GAGLIANO
Department of History, Loyola University of Chicago, 6525 N. Sheridan Rd., Chicago, Ill. 60626, U.S.A. 26 XII 77

As a historian who has studied the political, socioeconomic, and cultural aspects of coca consumption in Peru, I find this article, like much of the anthropological literature on coca chewing during the last decade, particularly interesting because it contributes to the strengthening of scientific inquiry into an Andean practice which historically has generated far more polemics than reasoned explanations. In the present century, the rise of an intense coca prohibitionist movement in Peru, which became associated with the Indianist programs of sociopolitical reformers and influenced the kinds of research many investigators selected, seriously hampered the impartial study of the relationship between coca chewing and high-altitude stress. As Fuchs suggests, much of the coca literature published in Peru during the 1940s, for example, focused primarily on poor nutrition as a reason for chewing coca and either ignored or minimized other possible motivations (see, among others, Kuczynski-Godard and Paz Soldân 1948, Sâenz 1945). Monge's (1946) speculation that the coca habit might be beneficial because it seemed to increase muscular efficiency at high altitudes contributed to the polarization of Peruvian coca researchers for several years. Until his untimely death in 1950, Carlos Gutierrez Noriega attempted to refute Monge's speculation in articles such as his 1948 "Errores sobre la interpretación de cocaismo en las grandes alturas," in which he expressed concern that Monge's opinion and scholarly reputation would obstruct the campaign to eradicate coca chewing. Carlos Ricketts, who as a senator in the 1920s introduced legislation to establish a national coca monopoly, also joined in the controversy. His 1954 criticism of the Monge position emphasized the absence of coca chewing among Ecuadorian Indians who lived at altitudes comparable to those of the coca chewers in Peru and Bolivia. The division among Peruvian scientists was still evident when Monge invited me to present a paper analyzing the historical literature on coca chewing and environmental adaptation in the Andes at the 37th International Congress of Americanists in 1966.

For various reasons, the published research during the last decade concerning the relationship between coca chewing and high-altitude stress has assumed a significantly different character from the earlier polemics. The restrained and cautious Fuchs article impresses me as an important complement to the findings of Garruto and Hanna, among others. Physical anthropologists are far more qualified than I to judge the validity of the model he proposes. His article is of value to the historian in that it adds perspective and balance to the study of motivation in coca chewing, as well as suggesting how scientific findings might influence political and social policies regarding the coca habit in Peru.

by Solomon H. Katz

Department of Anthropology, University of Pennsylvania, 33d and Spruce Sts. F1, Philadelphia, Pa. 19104, U.S.A. 8 I 78

The hypothesis that traditional coca chewing leads to an adaptive decrease in erythropoietin production and hence a decrease in the polycythemia which Mazess (1970) has aptly termed a "maladaptation" for high-altitude natives is attractive and important. The proposed mechanism also is plausible when we consider the many known and suspected pharmacological effects of coca alkaloids (principally cocaine) upon a number of regulatory centers of the hypothalamus. Moreover, traditional coca chewing is principally a high-altitude practice, and the hypothesis linking coca with decreased erythropoietin secretion, if confirmed, would be the only effect that would directly counter the polycythemic effects of low oxygen stress at high altitudes. Such a confirmation might shift the interpretation and conclusions of many previous high-altitude investigations carried out on modern native populations that did not include a research design controlling for the differential effects of coca chewing on hematocrit levels.

Perhaps the most significant clarification that this paper needs is that the proposed mechanism is only a hypothesis which has not yet been tested and that its confirmation will not necessarily exclude findings on other effects of coca chewing. While it is obvious to me that a formal test of the hypothesis would be productive, there are, nevertheless, other tests that could be performed with existing data. These include the following brief suggestions:

1. If coca chewing does play a significant role in altitude adaptation by reducing polycythemia (as measured by hematocrit values), then there should be a relationship between altitude and amount of coca chewed under traditional circumstances (this would probably exclude the more recent spread of coca chewing by highlanders migrating to the lowlands). Though one of Murra's papers is referenced in the bibliography, there may be enough data on traditional practices in his and other ethnographies and historical accounts to assemble a sufficient sample to test this epidemiological hypothesis further.

2. Although there is evidence for estrogen's having an inhibitory effect on erythropoietin secretion, it is also well known that the adult female has a lower hematocrit value than the male directly because of blood loss due to monthly menstrual flow. Following menopause, this mechanism for the loss of erythrocytes disappears and the hematocrit value rises to the same level as adult males'. In this regard, it is important to determine if the hematocrit value of coca-chewing postmenopausal women is lowered to menstrual levels and/or lowered when compared with suitable control populations.

3. The pharmacology of coca chewing is complicated by variations in alkaloids contained in the leaves. Its atropine-like activity probably derives from the fact that cocaine and atropine share an amino alcohol, ecgonine, which is thought to bind the receptor site for acetylcholine and hence interfere with neurotransmission. However, as Fuchs points out for cocaine (the principal and best known alkaloid from Andean coca leaves), it does not show the same effects as atropine; for example, it also has important and incompletely understood effects in blocking the uptake of norepinephrine, dopamine, and serotonin (for an excellent review, see Ellinwood and Kilbey 1977). Also, the metabolites of cocaine all yield various forms of ecgonine that may be active in blocking secretion of erythropoietin. Therefore, it may be premature to draw any further conclusions on the specific effects of coca chewing on erythropoietin secretion without specific tests of the efficacy of cocaine and these ecgonine metabolites. Such tests could be designed using direct techniques for measurement of erythropoietin or indirectly measuring its effects on hematocrit levels over a suitable time interval in controlled studies. While data of the type Buck et al. collected are necessary to support the hypothesis that there is an effect of coca chewing on hematocrit levels at lower altitudes, they may not be *sufficient* to confirm the hypothesis without studies specifically designed to answer this question at high altitudes. Also, without making a number of questionable statistical assumptions or without reanalyzing Buck et al.'s data for each subject, it is impossible to determine whether the relative significance of coca chewing was greater or less than that of other factors in changing the hematocrit level, since data on coca chewing represented a subsample of the original population.

At a broader level, this paper represents another important effort to integrate anthropological observations on traditional patterns of consumption of pharmacologically active plants within a biological and behavioral context. This biocultural approach is important not only for the understanding of the significance of long-term traditional practices for human adaptation and evolution, but also for the further expansion of our knowledge of a traditional practice which has been socially and politically condemned.

by MICHAEL A. LITTLE
Department of Anthropology, State University of New York at Binghamton, Binghamton, N.Y. 13901, U.S.A. 29 XI 77

The author has taken up a formidable problem which I hope will be pursued beyond the level of explanatory hypotheses and model construction. I can understand his fascination with patterns of coca use in the Andes; it has been the center of controversy for many years. The main points of his argument, as I understand them, are: (1) coca leaf mastication with lime is a more common practice at high altitudes than at lower elevations; (2) this relationship is likely to reflect a biobehavioral adaptation to hypoxic stress; (3) one biological response to hypoxia is polycythemia, which is detrimental because of a concomitant increase in blood viscosity; (4) there is evidence that coca use at high altitude depresses erythropoiesis; (5) then, coca-induced depression of erythropoiesis will reduce polycythemic stress, and this will improve the health of the Andean native. This is, of course, a simplification of an argument for which a reasonable amount of documentation is provided. My own interpretation is that the argument is not a very strong one and that the evidence is largely circumstantial. A discussion of the points noted above follows:

1. Coca chewing does appear to be altitude-related; unfortunately, so are oxygen pressure, temperature, diet, disease patterns, subsistence, and general cultural patterns of the Quechua Indian. As an important sociocultural element in highland native life, coca use would be expected to persist in those areas where its integration is greatest. Migrants to the lowlands may very well give up the practice because of increased social mobility or general shifts in cultural practices.

2. Whether or not coca use is an adaptation to altitude stresses can only be determined by careful and detailed experimental and field observational studies. These are possible but difficult to conduct. For example, one problem with studies at elevations greater than 3,800–4,000 m in Peru is that adult Indian nonusers of coca are practically nonexistent. Hence, comparisons of chewers vs. nonchewers in studies of long-term effects of the drug are likely to be limited to Indians vs. mestizos (or cholos). Coca use is only one of the many variables which distinguishes these two populations. At lower elevations, as in the Cachicoto sample of Buck et al. (1968) at 720 m, coca users are likely to be recent migrants from the highlands to the tropical forest, whereas nonusers are likely to be more permanent residents. These problems make matched controls very difficult to arrange.

3. It is by no means clear that moderate polycythemia (red blood count of $5.5–6.5 \times 10^6/\text{mm}^3$) is detrimental at high altitude, although few would argue that severe polycythemia in chronic *soroche* (red blood count of $8–9 \times 10^6/\text{mm}^3$) is not pathological. It is important to consider the degree of polycythemia when discussing its relative benefit or harm. Mazess (1970) has reviewed some of the aspects of blood circulation and oxygen transport at high altitude and discussed how increased capillarization may reduce somewhat the detrimental effects of increased blood viscosity from polycythemia. Moreover, a slow capillary blood flow from increased viscosity, despite increased capillarization and wider-caliber capillaries, may assist oxygen transfer to tissues by maintaining a high capillary pressure (Velásquez 1976). The physiological and biochemical mechanisms that come into play in order for the body to accommodate the hypoxic stress are manifold and complex in their interaction. Polycythemia is merely one of these.

4. The neurohormonal relationships between coca alkaloids and erythropoiesis that are discussed by the author are, in many cases, only postulated or not fully demonstrated. The second source of evidence cited in support of the depressing effect of coca use on erythropoiesis is the investigation by Buck, Sasaki, and Anderson (1968) in Cachicoto, Peru. In this investigation, attempts were made to control for age, sex, and occupation, but samples were not balanced for ethnic affiliation: Indians and mestizos were equally represented among coca chewers, but nearly 80% of nonchewers were mestizos, who might have had quite different diets than the underrepresented nonchewer Indians.

5. Finally, the evidence that reduced polycythemia will improve the health of the Andean native appears inconclusive. On the one hand, venous inflammations and pulmonary edema at high altitude may be related to polycythemia (see Mazess 1970, Garruto 1976). On the other hand, cardiovascular disease appears to be lower in incidence in high-altitude than in sea-level populations (see Way 1976). It may be that although polycythemia is an imperfect adaptation to altitude-induced hypoxia, its importance in facilitating oxygen transport outweighs the disadvantages of increased blood viscosity, particularly in light of the balancing effect of other physiological mechanisms.

Basic questions concerning the effects of coca use on body functions can only be approached, however, when we have accurate information on amounts of coca alkaloids that actually find their way into the circulatory system. Techniques are available for the detection of cocaine and cocaine metabolites from blood plasma and urine (Bastos and Hoffman 1974, Jain et al. 1977, Jatlow and Bailey 1975, Wallace et al. 1977). Collection of field specimens followed by biochemical analysis should constitute the first basic study before continuing discussion of the function of coca at high altitude.

by RICHARD B. MAZESS
Department of Anthropology, University of Wisconsin, Madison, Wis. 53706, U.S.A. 9 XI 77

Fuchs has presented an interesting hypothesis, but there is unfortunately little direct substantiation. I feel that some caution should be exercised in isolating the individual's motivation for a behavior from the stated motivation, and both of these need to be separated from the real and putative effects of that behavior. There is a great deal of emotional charge associated with "coca chewing"; the careful investigator will have to examine it as if it were tobacco chewing or thumb sucking. The author is to be congratulated on his recognition that polycythemia may be a problem rather than an adaptation.

by E. PICÓN-REÁTEGUI
Centro de Investigación, Instituto de Biología Andina, Universidad Nacional Mayor de San Marcos, Apartado 5073, Lima 1, Peru. 27 XII 77

The author's thesis that coca chewing may be beneficial in mitigating the effects of hypoxia through its action on blood formation in high-altitude residents is very interesting, but evidence will be needed before it can finally be accepted.

To demonstrate his conception, the author disregards a universally accepted fact: the increase in the number of erythrocytes as a physiological response to hypoxic conditions (Viault 1891, Hurtado, Merino, and Delgado 1945, Hurtado 1964, Pugh 1964). The observation that anemias are "well tolerated" in high-altitude-dwellers (Monge and Monge 1966) is not enough to permit the inference that the increase in erythrocytes is not a necessary adjustment to altitude, but a pathological process leading inexorably to chronic mountain sickness. It is not unusual to find sea-level residents who, to a certain extent, live an active life, in spite of displaying only about 4 g of hemoglobin per 100 ml of blood. However, nobody would dare to conclude from this that it is unnecessary to have 15 g of hemoglobin and that a person who has such a hemoglobin concentration must be suffering a symptomatology compatible with a diagnosis of polycythemia vera.

According to the proposed theory, the hematopoietic activity in this process is arrested and its "symptomatology of fatigue and headaches" relieved by the chewing of coca leaves, through which "antimuscarinic substances entering the bloodstream of coca chewers may depress erythropoiesis by depressing the critical areas of the posterior hypothalamus." It must be remarked that the average inhabitant of high altitudes, with a relatively higher hematocrit value, does not complain of more frequent headaches than his counterpart at sea level, and his work capacity is similar to (Velásquez 1964, Mazess 1969) or greater than (Hurtado 1966) that of the fit young person at sea level.

I am not sure that the sensations of hunger and thirst would be dulled in coca chewers. In a controlled experiment carried out with coca chewers living at an altitude of 3,900 m, I found food intake much the same (about 2,900 Kcal/day) during a period of coca chewing and during another without chewing. The men maintained body weight, which suggests that this amount of food was their usual calorie intake. A perusal of Ciuffardi's (1949) data suggests that his coca chewers also were in caloric balance; the water available to the body (from the meals plus from oxidation) was similar in both periods (about 3,500 ml/day).

As far as I am aware, the beneficial effects of coca leaves on the erythrocyte level of chewers or on the symptomatology of chronic mountain sickness have never been suggested either by scientific publications or by Quechua or Aymara folklore. A hemoglobin concentration of 18.0 ± 0.2 g and a hematocrit value of 51.9 ± 0.5% were recorded in the coca chewers of my experiment, and similar figures were recorded in nonchewers of the locality.

Factors other than coca chewing may have affected the erythrocyte counts in the studies of Buck et al. (1968). It is worth noting that both the prevalence of hookworm infestation (73.2% of the chewers and 58.5% of the controls) and its intensity (36.6% of chewers and 17.1% of the controls showed moderate intensity, i.e., 10 eggs/slide) were higher in the chewers. It is also of interest that there had been a recent influx of Quechuas into Cachicoto from high altitudes at the time the study was undertaken (Buck et al. 1968). In recent migrants from high altitudes, an arrest in erythrocyte production has been reported (Reynafarje 1966). The lower erythrocyte levels in coca chewers than in controls, at the same level of hookworm infestation, may well be explained by the inferior nutritional state in the chewers (Buck et al. 1968) as well as by a physiological arrest in erythrocyte production in newcomers from high altitudes.

The sources of iron provided by *cha'qo* may not be available at Cachicoto, and, since the leaves are not swallowed, the nutrients in them may not be utilized. We have found similar amounts of minerals, including iron, in intact leaves and in chewed ones. Other nutrients, such as thiamine, may be destroyed by the alkaline medium.

by LOWELL E. SEVER
Division of Epidemiology, School of Public Health, University of California, Los Angeles, Calif. 90024, U.S.A. 28 XI 77

This paper, in developing an interesting hypothesis relating cultural and biological interactions in high-altitude populations, stimulates several questions regarding coca use and the selective process in these populations. Consideration of these questions may be useful.

It is a truism of evolutionary thought that natural selection involves differential rates of reproduction and that factors which influence pregnancy outcome can be of major evolutionary significance (Sever n.d.). With regard to Fuchs's paper, what are the possible relationships between high altitude, coca use, and reproductive success? The adverse effects of high altitude on reproductive performance have been clearly documented in both Peru and the United States (Haas 1976, Hoff and Abelson 1976, McClung 1969) Much of the adverse effect can be attributed to problems of oxygen exchange between mother and fetus.

Though space limitations do not allow full development of the topic, it is interesting to consider possible relationships between coca use and placental function. As coca use by women is highest at high altitude, it is important to know if women continue to use coca during pregnancy. McClung (1969) reported that none of the 73 mothers in her study at Cuzco used coca. If coca is used by women at high altitude during pregnancy, it could affect fetal oxygenation in at least two ways, by decreasing placental blood flow and by reducing polycythemia.

According to Longo, Hill, and Power (1972), transfer of oxygen across the placenta is influenced by several factors, including maternal and fetal placental blood-flow rates. If coca alkaloids, which are peripheral vasoconstrictors, act as placental vasoconstrictors, what effect will this have on oxygen transfer across the placenta? One would assume that the vasoconstrictive action would decrease blood flow in the maternal vessels of the placenta and adversely affect oxygenation of the fetus. If, in addition, these compounds are capable of crossing the placenta, they could also affect the fetal vessels, further decreasing oxygen transfer.

The effect of coca on erythropoiesis, as reflected in lower hematocrit values, could also influence fetal oxygenation. Metcalfe, Novy, and Peterson (1967) include maternal polycythemia as one of four adaptations which permit successful reproduction at high altitude. If this is the case, it would appear that reduction of polycythemia in the pregnant woman would be maladaptive. As Haas (1976:179) has noted, "The role of maternal adaptation to high altitude, especially as it relates to child bearing, should not be overlooked."

It is important to note that the adverse effects of polycythemia may not be as clearly established as the author concludes. According to Hultgren and Grover (1968:127), data from Peru suggest "that if secondary polycythemia ceases to be advantageous by increasing blood viscosity, then this must occur at hematocrits above 60 percent." The data in figure 1, from Buck et al. (1968), show that less than 5% of the hematocrit values in the nonchewers were above the 60% level. Garruto (1976), in an important discussion of Quechua hematology, reported only one individual out of 39 adult Nuñoa Quechua with a hematocrit value greater than 60%. The lowering of hematocrit values in coca chewers, as discussed by Fuchs, may not be adaptive if the levels in the nonusers are not detrimental.

by D. TYAGI
Anthropological Survey of India, Northwestern Section, 51/7 Hardwar Rd., Dehra Dun 298001, India. 20 XII 77

Fuchs has offered an interesting, thoughtful, and logical hypothesis. The people of the Andes chew coca mainly to reduce the pain and dizziness associated with working at high altitude and the sensation of cold and to increase strength and energy and minimise hunger; the literature largely supports these reasons for coca chewing. Accepting the view that coca chewing is not "merely 'an addiction,' 'a habit,' or even a pleasurable activity," but is related to high-altitude stress, Fuchs proposes a mechanism by which "coca chewing may indeed aid individuals who suffer from hypoxia-induced chronic mountain sickness." The proposal seems plausible on the basis of the available data, but it should be tested with more field and laboratory research before we finally accept it.

by CORINNE SHEAR WOOD
Department of Anthropology, California State University, Fullerton, Calif. 92634, U.S.A. 16 XI 77

Fuchs's proposal is a provocative attempt to discern physiological value in the cultural practice of coca chewing among the natives of the Bolivian and Peruvian Andes. He specifically speculates that the practice at high altitudes may be instrumental in reducing what may be an excessive erythropoietic response from individuals suffering from long-term hypoxia associated with high altitudes.

One welcomes such proposals, particularly in the sense that physical anthropologists—indeed, all students of human behavior—would like to have demonstrated that there are underlying functions associated with cultural practices that, on the surface, seem puzzling if not counter-survival. Unfortunately, Fuchs's proposal must at present be judged as suffused with much contradictory evidence.

Primarily, the hematocrit levels cited (table 4 and figure 1), not only for the coca chewers but for the controls as well, are hardly in the range where polycythemia would be diagnosed. Even at the extreme end of the range, where the packed-cell volumes approach polycythemia, less than 3% of the controls (nonchewers) are affected, as compared with approximately 2% of the coca chewers. (One wonders also at the dearth of reports of therapeutic phlebotomy as a common practice in this region of the world, in contradistinction to its frequent usage elsewhere.) Secondly, a substance that acts as a vasoconstrictor would hardly be beneficial in the presence of increased blood viscosity. Thirdly, under conditions of expanded iron requirements, an appetite depressant would be grossly suspect from a physiological perspective.

On the other hand, the well-known altitude adaptations, including elevated red blood cell counts, certainly have been adequately documented historically and, to a point bordering on polycythemia, are an obvious selected response to conditions of hypoxia. I would argue, from personal observation, that the response itself does not become painful, or produce symptoms of headache, epistaxis, or bleeding gums and associated symptoms, until higher levels than those reported by Fuchs are encountered. Wintrobe (1951), for example, began to observe polycythemia symptoms when hematocrit values exceeded 60. In addition, he recorded values of 64 and above for healthy males living at approximately 15,000 ft. The extremes of hematocrits encountered there were 76, quite beyond the range reported by Fuchs.

Nevertheless, Fuchs's proposal certainly deserves further investigation, employing strict controls for factors such as effects of the metals mined on the erythropoiesis system, dietary influences, and the presence of pain from other sources.

On the last point, one might cite the negative selection value of caries and periodontal disease whose symptoms are masked by the anesthetic effects of coca chewing. Indeed, in this region, where trepanned skulls were found in such relative abundance, one may speculate about a relationship between the anesthetic effects of coca chewing and the subsequent periodontal distress which the trepanners may have sought to relieve. That pain is an important part of life in these regions is further attested to by the reports of travelers and fieldworkers who find that such pain relievers as aspirin can assume the value of currency in barter exchanges. I have not been convinced by Fuchs's paper that the pain is derived from effects of elevated erythrocyte levels, but I would value further studies.

Reply

by ANDREW FUCHS
Philadelphia, Pa., U.S.A. 30 I 78

This article was written to assess the available ethnographic, physiological, and pharmacological data on coca chewing and to propose the hypothesis that coca use in the Andes may be related to the polycythemic stress endured by Quechua and Aymara Indian populations in that region. While virtually all of the commentators agree that the hypothesis merits testing, there is little consensus on the interpretation of currently available studies of coca use and high-altitude stress. Furthermore, no evidence has been presented in the commentary which is sufficient to reject the hypothesis, although it may indeed be refuted by appropriate research in the future. The questions raised by the commentators fall into three broad categories: (1) the circumstances under which the erythropoietic response to hypoxia is beneficial or debilitating; (2) the details of coca pharmacology; and, (3) the quality, application, and interpretation of the available data.

Reviewers differed sharply on the extent to which the erythropoietic response is beneficial or debilitating. Mazess agrees that polycythemia is often best regarded as a problem rather than as an adaptation, while Picón-Reátegui feels that I have "disregarded a universally accepted fact: the increase in the number of erythrocytes as a physiological response to hypoxic conditions." Actually, the degree to which the erythropoietic response is beneficial or debilitating is largely dependent on its intensity. For example, Sever and Wood refer to studies which indicate that clinical polycythemia generally becomes manifest only when hematocrit levels exceed 60%. Importantly, the relationship between viscosity and hematocrit levels is not linear, and differences of only a few percentage points above or below this figure may have a great effect on blood viscosity (Pirofsky 1953). Virtually all available data for Andean inhabitants of altitudes over 4,500 m indicate hematocrit values averaging 60% or greater (Garruto 1973:166).

Many of the commentators (Frisancho, Wood, Little, Sever, Picón-Reátegui) may have misunderstood my use of Buck et al.'s data, in that they argue that the hematocrit levels indicated in figure 1 are not in the clinically significant range for polycythemia. Indeed, they are not, and it is clear that my use of the graph requires further explanation. To my knowledge, data that would indicate that coca use reduces hematocrit values in high-altitude natives from a clinically significant level to a nonsignificant one do not exist. On the other hand, the graph does indicate that, at low altitude, coca chewers had lower hematocrit values than nonchewers in a study which incorporated reasonable controls for disease and nutrition. In the context of the pharmacological evidence, this is taken to indicate that the coca alkaloids may have an effect on erythropoiesis. Since the physiological regulatory mechanism for erythropoiesis is presumably the same in high- and low-altitude dwellers, the facts that this study was not conducted at high altitude and that the observed hematocrit values were not in the clinically significant range are irrelevant to that point. It is even arguable that, given Little's assertion that nonuser control subjects for coca-chewing studies are almost nonexistent at very high altitudes, data collected at lower altitudes may be the best obtainable. Thus, while Katz is almost certainly correct in suggesting that Buck et al.'s data are insufficient to confirm the hypothesis at high altitudes, Frisancho is almost certainly incorrect in implying that they are sufficient to reject it.

There is also little agreement on the specifics of coca pharmacology. Burchard argues that Montesinos (1965) found that hydrolysis of cocaine begins in the mouth *because* of the action of the alkali with which it is chewed. However, alkaloids such as cocaine become much more effective in the presence of a base (Ritchie and Cohen 1975:383). Further, Montesinos nowhere suggests that all of the liberated cocaine is broken down into its metabolites while it is still in the oral cavity. In fact, he concludes that most of the orally ingested cocaine is hydrolyzed as it crosses the intestinal mucosa. This implies that some cocaine is not hydrolyzed in the mouth. Finally, most of the work reported by Montesinos and his colleagues was performed *in vitro*, and nowhere in this work is there any indication that cocaine absorption was studied in native coca chewers; nor is there any indication that these investigators considered the capacity of the oral mucosa to absorb cocaine (Ritchie and Cohen 1975:387).

Clearly, as Katz and Little point out, we need to know more about the relative degree of norepinephrine potentiation and antimuscarinic activity resulting from coca chewing. In the absence of more specific data than are currently available, it is difficult to evaluate Wood's point that, since cocaine is a peripheral vasoconstrictor, it might aggravate rather than ameliorate the effects of polycythemia. At least three pharmacological possibilities need to be considered. First, if cocaine were the sole chemical agent involved (to the exclusion of ecgonine), vasodilation in skeletal muscles could be expected to accompany peripheral vasoconstriction (Ganong 1975:444). However, vasodilation in skeletal muscles is controlled through cholinergic nervous transmission, which could be inhibited by an antimuscarin such as ecgonine. Therefore, if both cocaine and ecgonine were involved, vasoconstriction would be a problem. This could be dynamically compensated for by any of a number of variables, including (1) increase in blood pressure as a direct result of vasoconstriction, (2) increased capillarization, known to occur at high altitudes (Mazess 1970:271), (3) increase in pulse due to the direct effect of both norepinephrine and antimuscarins on the heart, and (4) reduced hematocrit value. Finally, if ecgonine alone were responsible for the pharmacology of coca, vasoconstriction would not be a problem at all, although vasodilation of skeletal muscles might be somewhat inhibited.

That ecgonine acts much as atropine does is likely, although this little-known chemical certainly deserves more attention. It is especially interesting, I think, that Monge and Monge (1966:27) reported that Indians at high altitudes have low atropine sensitivity, since tolerance to this chemical is rapidly acquired in man (Dawson et al. 1969:407).

As for the quality, application, and interpretation of the available data, Katz makes the point that many high-altitude investigations carried out on modern native populations "did not include . . . a research design controlling for the differential effects of coca chewing on hematocrit levels." This lack of appropriate controls makes it difficult to assess some of the comments of Picón-Reátegui and Curtain. The former points out that inhabitants of high altitudes did not complain of more frequent headaches than those at low altitudes, and the latter suggests that increase in mean hematocrit and hemoglobin levels in individuals who move to high altitudes may not be significant. Without controls for coca use, I would argue that the studies on which these statements are based may be largely inapplicable.

Potentially the most serious counterevidence to the account I have proposed is Picón-Reátegui's report that, at 3,900 m, the hematocrit values of coca chewers and nonchewers were "similar." This finding is unfortunately unpublished, and, without further details, a reply is difficult. For one thing, the erythropoietic response is obviously a long-term one, so the amount of time involved in this study is critical. If, on the other hand, the study was conducted with native chewers and nonchewers whose normal behavior was not intentionally altered for the purposes of the study, I would argue that chewers may be just those individuals who, without coca, would indeed have high hematocrit values. If this were the case, "similar" values could be interpreted to support the hypothesis I have proposed.

Finally, Wood's comment that an appetite depressant would not be helpful for a marginally nourished population requires comment. Picón-Reátegui reports that coca users in his study maintained carbohydrate balance and ate no less than nonusers. Since the relationship between coca use and the reduced perception of hunger is well documented, this finding implies that the reduced *sensation* of hunger may not cause coca chewers to *eat less* than their counterparts who don't chew. If, in fact, coca consumption has no effect on dietary intake, this would appear to strengthen the likelihood that Buck et al.'s findings are explained by the action of coca leaves rather than by differential food intake.

In conclusion, it is clear that there is a need for theoretical reconsideration of previous studies beyond what has been presented here and for more data than are currently available regarding the phenomenon of coca chewing in the high Andes. In light of the comments of Gagliano and Mazess on the highly charged atmosphere surrounding the coca question, and in view of the efforts of the governments of Peru and Bolivia to discourage the use of the coca leaf, the need for such interdisciplinary study, combining empirical enquiry with compassion and respect for the Andean Indian, cannot be overemphasized.

References Cited

ANAND, B. K., and J. R. BROBECK. 1951. Localization of a "feeding center" in the hypothalamus of the rat. *Proceedings of the Society for Experimental Biology and Medicine* 77:323–24.

ASHLEY, RICHARD. 1975. *Cocaine.* New York: St. Michael's Press.

BAKER, PAUL. 1968. "Human adaptation to high altitude," in *High altitude adaptation in a Peruvian community.* Occasional Papers in Anthropology of the Department of Anthropology, Pennsylvania State University, 1.

BAKER, PAUL, and MICHAEL A. LITTLE. Editors. 1976. *Man in the Andes: A multidisciplinary study of high-altitude Quechua.* Scranton, Pa.: Dowden, Hutchinson and Ross. [ARF]

BAKER, PAUL, RICHARD MAZESS. 1963. Calcium: Unusual sources in the highland Peruvian diet. *Science* 142:1466–77.

BASTOS, M. L., and D. B. HOFFMAN. 1974. Comparison of methods for detection of amphetamines, cocaine, and metabolites. *Journal of Chromatographic Science* 12:269–84. [MAL]

BOLTON, RALPH. 1973. Aggression and hypoglycemia among the Qolla: A study in psychobiological anthropology. *Ethnology* 12:227–57.

———. 1976. Andean coca chewing: A metabolic perspective. *American Anthropologist* 78:630–34. [CCC]

BUCK, A., T. SASAKI, and R. ANDERSON. 1968. *Health and disease in four Peruvian villages.* Baltimore: Johns Hopkins Press.

BUCK, A., T. SASAKI, J. HEWITT, and A. MACRAE. 1968. Coca chewing and health: An epidemiologic study. *American Journal of Epidemiology* 88:159–77.

———. 1970. Coca chewing and health: An epidemiologic study among residents of a Peruvian village. *Bulletin on Narcotics* 22(4):23–32.

BURCHARD, RODERICK E. 1975*a*. "Coca chewing: A new perspective," in *Cannabis and culture.* Edited by Vera Rubin, pp. 463–84. The Hague: Mouton. [REB]

———. 1975*b*. Coca leaf, the "hot-cold" syndrome, and peasant biocultural adaptation. Paper presented at the 75th annual meeting of the American Anthropological Association, San Francisco, Calif. [REB]

———. 1976. Myths of the sacred leaf: Ecological perspectives on coca and peasant biocultural adaptation in Peru. Unpublished Ph.D. dissertation, Indiana University, Bloomington, Ind.

———. 1977. Coca use and the management of carbohydrate metabolism problems in the Andean highlands and the Amazonian lowlands. Paper presented at the annual meeting of the Florida Academia of Sciences, Gainesville, Fla.

CABIESES MOLINA, FERNANDO. 1946. La acción antifatigante de la cocaína y la habituación a la coca en el Perú. *Anales de la Facultad de Medicina* (Lima) 29:316–67.

CÁRDENAS, M. 1952. Psychological aspects of coca addiction. *Bulletin on Narcotics* 4(2):6–9.

CHINN, K., and J. HANNON. 1969. Efficiency of food utilization at high altitude. *Federation Proceedings* 28:944–47.

CIUFFARDI, T. 1949. Excreción renal de alcaloides en habituados a la coca: Contribución a la química del cocaismo. *Revista de Farmacología y Medicina Experimental* 2:18–93.

COOPER, JOHN M. 1949. Stimulants and narcotics. *Bureau of American Ethnology Bulletin* 143:525–58.

CRUZ, SANCHEZ, and ANGEL GULLÉN. 1948. Estudio químico de las substancias alcalinas auxiliares del cocaismo. *Revista de Farmacología y Medicina Experimental* 1:209–15.

CUTTING, W. C. 1972. 5th edition. *Handbook of pharmacology.* New York: Appleton-Century-Crofts.

DAWSON, R. M. C., D. ELLIOTT, W. H. ELLIOTT, and K. M. JONES. 1969. *Data for biochemical research.* Oxford: Oxford University Press.

ELLINWOOD, H. J., and M. M. KILBEY. 1977. *Advances in behavioral biology. Vol. 21. Cocaine and other stimulants.* New York: Plenum. [SHK]

ERSLEV, A. J., L. KAZAL, and O. MILLER. 1971. A renal lipid inhibitor

of erythropoietin. *Transactions of the Association of American Physiologists* 84:212–16.
FABREGA, H., and P. MANNING. 1972. Health maintenance among Peruvian peasants. *Human Organization* 31:243–56.
FISHER, J., A. SAMUELS, and J. LANGSTON. 1968. Effects of angiotensin, norepinephrine, and renal artery constriction on erythropoietin production. *Annals of the New York Academy of Sciences* 149:308–17.
FRIED, W., C. GURNEY, and F. FESLER. 1971. "Effects of androgens on erythropoiesis," in *Renal pharmacology*. Edited by J. Fisher. New York: Appleton-Century-Crofts.
FRISANCHO, A. R. 1975. Functional adaptation to high-altitude hypoxia. *Science* 187:313–19. [ARF]
GALEANO, EDUARDO. 1973. *Open veins of Latin America*. Translated by Cedric Belfrage. New York: Monthly Review Press.
GANONG, WILLIAM F. 1975. 7th edition. *Review of medical physiology*. Los Altos, Calif.: Lange.
GARRUTO, RALPH. 1973. Polycythemia as an adaptive response to chronic mountain sickness. Unpublished Ph.D. dissertation, Pennsylvania State University, University Park. Pa.
———. 1976. "Hematology," in *Man in the Andes: A multidisciplinary study of high-altitude Quechua*. Edited by Paul T. Baker and Michael A. Little, pp. 261–82. Stroudsburg, Pa.: Dowden, Hutchinson and Ross. [CCC, MAL, LES]
GAY, G., D. INABA, C. SHEPPARD, and J. NEWMAYER. 1975. Cocaine: History, epidemiology, human pharmacology, and treatment. *Clinical Pharmacology and Toxicology* 8(2):149.
GOLDMAN, IRVING. 1948. Tribes of the Uaupés-Caquetá region. *Bureau of American Ethnology Bulletin* 143(3):763–98.
———. 1963. *The Cubeo*. Urbana: University of Illinois Press. [REB]
GOLTE, JUERGEN. 1970. "Algunas consideraciones acerca de la producción y distribución de la coca en el estado Inca." *Proceedings of the 38th International Congress of Americanists*, vol. 2, pp. 471–78. Stuttgart.
GOODMAN, A., and S. GILLMAN. 1975. 5th edition. *The pharmacological basis of therapeutics*. New York: Macmillan.
GRAY, G. M. 1973. Drugs, malnutrition, and carbohydrate absorption. *American Journal of Clinical Nutrition* 26:121–24. [REB]
GROLLMAN, A., and E. GROLLMAN. 1970. *Pharmacology and therapeutics*. Philadelphia: Lea and Febiger.
GUTIERREZ NORIEGA, CARLOS. 1944. Datos históricos sobre la habituación a la coca en el Perú. *Revista de Farmacología y Medicina Experimental* 3:341–453.
———. 1947. Alteraciones mentales producidas para la coca. *Revista de Neuro-Psiquiatría* (Lima) 10:145–76.
———. 1948. Errores sobre la interpretación del cocaismo en las grandes alturas. *Revista de Farmacología y Medicina Experimental* 1:32–68.
GUTIERREZ NORIEGA, CARLOS, and VICENTE ZAPATA ORTIZ. 1948. Observaciones fisiológicas y patológicas en sujetos habituados a la coca. *Revista de Farmacología y Medicina Experimental* 1:1–31.
HAAS, JERE D. 1976. "Prenatal and infant growth and development," in *Man in the Andes: A multidisciplinary study of high-altitude Quechua*. Edited by Paul T. Baker and Michael A. Little, pp. 161–79. Stroudsburg, Pa.: Dowden, Hutchinson and Ross. [LES]
HALVERSON, S. 1964. Effects of hypothalamic lesions on the erythrogenic response to hypoxia in rabbits. *Acta Physiologica Scandinavica* 61:1–19.
HANNA, JOEL M. 1971. Responses of Quechua Indians to coca ingestion during cold exposure. *American Journal of Physical Anthropology* 34:273–77.
———. 1974. Coca leaf use in southern Peru: Some biological aspects. *American Anthropologist* 76:281–95.
———. 1977. Use of coca leaf in southern Peru: Adaptation or addiction. *Bulletin on Narcotics* 29(1):63–75.
HEATH, D., and D. R. WILLIAMS. 1977. *Man at high altitude: The pathophysiology of acclimatization and adaptation*. Edinburgh-London: Churchill Livingston. [ARF]
HERNÁNDEZ DE ALBA, G. 1946. The highland tribes of southern Colombia. *Bureau of American Ethnology Bulletin* 143(2):915–60.
HOFF, CHARLES J., and ANDREW E. ABELSON. 1976. "Fertility," in *Man in the Andes: A multidisciplinary study of high-altitude Quechua*. Edited by Paul T. Baker and Michael A. Little, pp. 128–46. Stroudsburg, Pa.: Dowden, Hutchinson and Ross. [LES]
HULTGREN, HERBERT N., and ROBERT F. GROVER. 1968. Circulatory adaptation to high altitude. *Annual Review of Medicine* 19:119–52. [LES]
HURTADO, A. 1932. Studies at high altitude: Blood observations on the Indian natives of the Peruvian Andes. *American Journal of Physiology* 100:487–505.
———. 1964. "Animals in high altitudes: Resident man," in *Handbook of physiology. Section 4. Adaptation to the environment*. Edited by D.B. Dill, E. F. Adolph, and C. G. Wilber, pp. 843–60. Washington, D.C.: American Physiological Society. [EPR]
———. 1966. "Natural acclimatization to high altitudes," in *Life at high altitudes*, pp. 7–8. Pan American Health Organization Science Publication 140. [EPR]
HURTADO, A., C. MERINO, and E. DELGADO. 1945. Influence of anoxemia on the hematopoietic activity. *Archives of Internal Medicine* 75:284–323. [EPR]
JAIN, N. C., D. M. CHINN, T. C. SNEATH, and R. D. BUDD. 1977. Simultaneous gas chromatographic determination of cocaine, methadone, methaqualine, phencyclidine, and propoxyphene. *Journal of Analytical Toxicology* 1:192–94. [MAL]
JATLOW, P. I., and D. N. BAILEY. 1975. Gas chromatographic analysis for cocaine in human plasma, with use of a nitrogen detector. *Clinical Chemistry* 21(13):1918–21. [MAL]
KAUL, B., S. J. MILLIAN, and B. DAVIDOW. 1976. The development of a radioimmunoassay for detection of cocaine metabolites. *Journal of Pharmacology and Experimental Therapeutics* 199:171–78. [CCC]
KRANTZ, S., and L. JACOBSON. 1970. *Erythropoietin and the regulation of erythropoiesis*. Chicago: University of Chicago Press.
KUCZYNSKI-GODARD, MAXIME, and CARLOS E. PAZ SOLDÁN. 1948. *Disección del indigenismo peruano*. Lima. [JAG]
LA BARRE, WESTON. 1948. *The Aymara Indians of the Lake Titicaca altiplano, Bolivia*. American Anthropological Association Memoir 68.
LÉVY, J., and E. ZISSMANN. 1950. Dosage de fabiles quantités de cocaine en présence d'ecgonine. *Journal de Physiologie* 42:499–503. [REB]
LITTLE, MICHAEL. 1970. Effects of alcohol and coca on foot temperature responses of highland Peruvians during a localized cold exposure. *American Journal of Physical Anthropology* 32:233–42.
LONGO, LAWRENCE D., ESTHER P. HILL, and GORDON G. POWER. 1972. "Factors affecting placental oxygen transfer," in *Respiratory gas exchange and blood flow in the placenta*. Edited by Lawrence D. Longo and Heinz Bartels, pp. 345–93. Washington, D.C.: U.S. Department of Health, Education and Welfare. [LES]
LOW-BEER, THOMAS, and G. SCOTT. Polycythemia in androgen-dependent aplastic anaemia. *British Journal of Medicine* 1:197.
LOWIE, R. H. 1948. The tropical forest: An introduction. *Bureau of American Ethnology Bulletin* 143(3):1–191.
MCCLUNG, JEAN. 1969. *Effects of high altitude on human birth*. Cambridge: Harvard University Press. [LES]
MANGIN, WILLIAM P. 1970*a*. "Similarities and differences between two types of Peruvian communities," in *Peasants in cities*. Edited by William P. Mangin, pp. 20–29. Boston: Houghton Mifflin.
———. 1970*b*. "Urbanization case history in Peru," in *Peasants in cities*. Edited by William P. Mangin, pp. 47–54. Boston: Houghton Mifflin.
MARKHAM, CLEMENT. 1856. *Cuzco: A journey to the ancient capitol of Peru*. London: Hakluyt Society.
MARTIN, RICHARD. 1970. The role of coca in the history, religion, and medicine of South American Indians. *Economic Botany* 24:422–37.
MASON, J. ALDEN. 1957. *The ancient civilizations of Peru*. Harmondsworth: Penguin Books.
MAZESS, RICHARD B. 1969. Exercise performance at high altitude in Peru. *Federation Proceedings* 28:1301–6. [EPR]
———. 1970. Cardiorespiratory characteristics of adaptation to high altitudes. *American Journal of Physical Anthropology* 32:267.
MAZESS, RICHARD B., and PAUL BAKER. 1964. Diet of Quechua Indians living at high altitude: Nuñoa, Peru. *American Journal of Clinical Nutrition* 15:341–51.
MEDADO, P., G. IZAK, and S. FELDMAN. 1967. The effect of electrical stimulation of the central nervous system on erythropoiesis in the rat II: Localization of a specific brain structure capable of enhancing erythropoiesis. *Journal of Laboratory and Clinical Medicine* 69:776–86.
METCALFE, J., M. J. NOVY, and E. N. PETERSON. 1967. "Reproduction at high altitudes," in *Comparative aspects of reproductive failure*. Edited by Kurt Benirschke, pp. 448–57. New York: Springer. [LES]
MÉTRAUX, ALFRED. 1948. Tribes of Eastern Bolivia and the Madeira headwaters. *Bureau of American Ethnology Bulletin* 143(3):381–463.
MILLER, BENJAMIN, and CLAIRE KEANE. 1972. *Encyclopedia and dictionary of medicine and nursing*. Philadelphia: W. B. Saunders. [REB]
MISHKIN, BERNARD. 1946. The contemporary Quechua. *Bureau of American Ethnology Bulletin* 143(2):411–70.
MONGE, CARLOS. 1943. Chronic mountain sickness. *Physiological Reviews* 23:166–83.
———. 1946. El problema de la coca en el Perú. *Anales de la Facultad de Medicina* (Lima) 29:312–15. [JAG]
———. 1948. *Acclimatization in the Andes*. Baltimore: Johns Hopkins Press.
———. 1952. The need for studying the problem of coca leaf chewing. *Bulletin on Narcotics* 4(4):13–15.
MONGE, CARLOS M., and CARLOS C. MONGE. 1966. *High altitude diseases: Mechanics and management*. Springfield: Thomas.
MONTESINOS A., FERNANDO. 1965. Metabolism of cocaine. *Bulletin on Narcotics* 17(2):11–17.
MORTIMER, W. GOLDEN. 1901. *History of coca, "the divine plant" of the Incas*. New York: J. H. Vail.
MOULIN, J. 1971. Hématimétrie et cytologie en milieu tropical de

l'Amérique du Sud. Unpublished Ph.D. thesis, Université Paul-Sabatier, Toulouse, France. [CCC]

MURRA, JOHN V. 1967. "La Visita de los Chupachu como fuente etnológica," in *Visita de la Provincia de León de Huánuco en 1562, Iñigo Ortiz de Zúñiga*. Edited by John V. Murra. Huánuco: Universidad Nacional Hermilio Valdizán.

NAIL, RICHARD, ERIC GUNDERSON, and DOUGLAS KOLB. 1974. Motives for drug use among light and heavy users. *Journal of Nervous and Mental Disease* 159(2):131–36.

NIESCHULTZ, OTTO, and PAUL SCHMERSAHL. 1969. Untersuchungen über die bedeutung des kalkzusatzes beim kauem von coca-blättern. *Pharmakologische und Phytochemische* 21:178–83. [REB]

NUÑEZ DEL PRADO, OSCAR. 1973. *Kuyo Chico: Applied anthropology in an Indian community*. Chicago: University of Chicago Press.

PAULO, L., B. ROH, and J. FISHER. 1971. Inhibitory effects of atropine on erythropoietin production in rabbits. *Pharmacologist* 13:287.

———. 1972. Antagonism of erythropoietin production in rabbits by atropine. *Proceedings of the Society for Experimental and Biological Medicine* 139:207–10.

PÉREZ DE BARRADAS, JOSÉ. 1940. Antigüedad del uso de la coca en Colombia. *Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales* 3:323–26.

PETERSON, D., and M. HARDINGE. 1967. The effects of various environmental factors on cocaine and ephedrine toxicity. *Journal of Pharmacy and Pharmacology* 19:810–14.

PIROFSKY, BERNARD. 1953. The determination of blood viscosity in man by a method based on Poisevilles's law. *Journal of Clinical Investigation* 32:292–98.

PRANCE, GHILLEAN T. 1972. Ethnobotanical notes from Amazonian Brazil. *Economic Botany* 26:221–39. [REB]

PUGH, L. G. C. E. 1964. "Animals in high altitude: Man above 5,000 meters—mountain exploration," in *Handbook of physiology. Section 4. Adaptation to the environment*. Edited by D. B. Dill, E. F. Adolph, and C. G. Wilber, pp. 861–68. Washington, D.C.: American Physiological Society. [EPR]

RAKITA, L., D. GILLESPIE, and S. SANCETTA. 1965. The acute and chronic effects of phlebotomy on general hemodynamics and pulmonary functions of patients with secondary polycythemia associated with pulmonary emphysema. *American Heart Journal* 70:466–75.

REYNAFARJE, C. 1966. La policitemia de las grandes alturas. *Archivios del Instituto de Biologia Andina* 1:142–50. [EPR]

RICKETTS, CARLOS. 1954. La masticación de las hojas de coca en el Perú. *América Indígena* 14:116–17. [JAG]

RITCHIE, J. M., and PETER J. COHEN. 1975. "Cocaine, procaine, and other synthetic local anaesthetics," in *The pharmacological basis of therapeutics*, 5th edition. Edited by A. Goodman and E. Gillman. Philadelphia: Lea and Febiger.

RODRIGUEZ, ARGOS. 1965. Possibilities of crop substitution for the coca bush in Bolivia. *Bulletin on Narcotics* 17(3):13–20.

ROWE, JOHN H. 1946. Inca culture at the time of the Spanish Conquest. *Bureau of American Ethnology Bulletin* 143(2):183–330.

SÁENZ, LUIS. 1938. *La coca: Estudio médico-social de la gran toxicomania peruana*. Lima.

———. 1945. *El punto de vista médico en el problema indígena peruano*. Lima. [JAG]

SALGUERO-SILVA, H. 1971. Indices hematoicos normales en La Paz. MS. La Paz: Instituto Nacional de Salud Ocupacional.

SALSER, J. K., JR. 1970. Cubeo acculturation to coca and its social implications. *Economic Botany* 2:182–86. [REB]

SEVER, LOWELL E. n.d. Physical anthropology and problems of pregnancy outcome: Introduction and overview. *Yearbook of Physical Anthropology*. In press. [LES]

STEIN, W. W. 1961. *Hualcan: Life in the highlands of Peru*. Ithaca: Cornell University Press.

STEWARD, J. H. 1948. The Witotoan tribes. *Bureau of American Ethnology Bulletin* 143(3):749–62.

STEWARD, J. H., and A. MÉTRAUX. 1948. Tribes of the Peruvian and Ecuadorian Montaña. *Bureau of American Ethnology Bulletin* 143(3):535–656.

STONER, H. B., and R. LITTLE. 1969. Studies on the mechanism of shock: The effect of cocaine and theophylline on the temperature response to injury in the cold-acclimatized rat. *British Journal of Experimental Pathology* 50(2):97–106.

STRUIMA, M., and M. PHILLIPS. 1963. Effect of red cell factors on the relative viscosity of whole blood. *American Journal of Clinical Pathology* 39:464–74.

TAKAKU, F. 1961. Effect of bilateral section of the splanchnic nerve on erythropoiesis. *Nature* 191:500.

TSCHOPIK, HARRY. 1946. The Aymara. *Bureau of American Ethnology Bulletin* 143(2):501–73.

———. 1951. The Aymara of Chucuito, Peru. *Anthropological Papers of the American Museum of Natural History* 44:137–308.

UNITED NATIONS. 1950. *Report of the Commission of Enquiry on the Coca Leaf*. Economic and Social Council Special Supplement 1.

VELÁSQUEZ, T. 1976. "Pulmonary function and oxygen transport," in *Man in the Andes: A multidisciplinary study of high-altitude Quechua*. Edited by P. T. Baker and M. A. Little, pp. 237–60. Stroudsburg, Pa.: Dowden, Hutchinson and Ross. [MAL]

VERZAR, F. 1955. Nutrition as a factor against addiction. *American Journal of Clinical Nutrition* 3:363–73.

VIAULT, E. 1891. Sur la quantité d'oxygéne contenue dans le sang des animaux des hauts plateaux de l'Amérique du Sud. *Comptes Rendus de l'Acadêmie des Sciences* 112:295–98. [EPR]

VITTI, T., R. E. BURCHARD, and R. ROSCOE. n.d. A preliminary study of the kinetics of the alkaline-hydrolysis of cocaine. MS. [REB]

WALLACE, J. E., H. E. HAMILTON, J. G. CHRISTENSON, E. L. SHIMEK, JR., P. LAND, and S. C. HARRIS. 1977. An evaluation of selected methods for determining cocaine and benzoylecgonine in urine. *Journal of Analytical Toxicology* 1:20–26. [MAL]

WARD, M. 1975. *Mountain medicine: A clinical study of cold and high altitude*. London: Crosby Lockwood Staples. [ARF]

WAY, A. B. 1976. "Morbidity and postneonatal mortality," in *Man in the Andes: A multidisciplinary study of high-altitude Quechua*. Edited by P. T. Baker and M. A. Little, pp. 147–60. Stroudsburg, Pa.: Dowden, Hutchinson and Ross. [MAL]

WEIL, ANDREW. 1975. Letters from Andrew Weil. *Journal of Psychedelic Drugs* 7:401–12. [REB]

WEINREB, N., and C. F. SHIH. 1975. Spurious polycythemia. *Seminars in Haematology* 12:397–407.

WILLIAMS, ROBERT H. 1968. *Textbook of endocrinology*. Philadelphia: W. B. Saunders. [REB]

WINTROBE, MAXWELL M. 1951. 3d edition. *Clinical hematology*. Philadelphia: Lea and Febiger. [CSW]

WOLFF, PABLO OSWALDO. 1950. "Annotated bibliography on the effects of chewing coca leaf," in *Report of the Commission of Enquiry on the Coca Leaf*, pp. 119–96. United Nations Economic and Social Council Special Supplement 1.

ZAPATA ORTIZ, V. 1952. The problem of the chewing of the coca leaf in Peru. *Bulletin on Narcotics* 4(2):26–33.