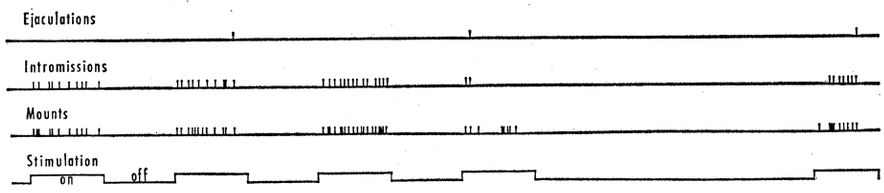

Fig. 1. Copulation during brain stimulation. Electrical stimulation in a posterior hypothalamic self-stimulation site elicits immediate sexual behavior which persists even after ejaculation. Each "on" period lasts 3 minutes.

sistent phenomenon. In one test session lasting 66 minutes (eleven 3-minute periods of stimulation), 115 mounts, 82 intromissions, and 6 ejaculations were recorded. During the eleven 3-minute periods, without stimulation there were only 5 mounts, 5 intromissions, and no ejaculations. Week after week the effect was reproducible in all ten animals. In one animal, stimulus-bound copulation occurred on each of 7 test days over a 4-month period.

Stimulation of the posterior hypothalamus induced copulation, not feeding. Four rats were tested with food, and then with both food and a female rat. Stimulation never elicited eating. If a male in the process of eating was stimulated, he stopped eating and mounted the female.

Males were highly motivated to mate during stimulation. This was demonstrated in two animals. A plexiglass partition with a closed door, separated the male and the female. The door opened when the male pressed a small bar protruding from the partition. If the male did not seek the female and did not copulate within 10 seconds, he was again confined to his side of the chamber. If he did enter the female's compartment and did copulate, he was allowed one intromission before he was returned to his side of the chamber. One rat had prior training in opening the door; the other was trained during stimulation. In both cases, the animals pressed the bar significantly more often when the stimulus was on than when it was off. The animal without prior training pressed the bar to open the door 29 times during nine stimulation periods, and only one time during alternate nonstimulation periods. He copulated within 10 seconds after 14 of the 29 bar presses. The fact that stimulation motivated animals to emit a learned response arbitrarily required by the experimenter shows that stimulus-bound copulation was neither mere indiscriminate activation nor rigid reflex. Stimulation elicited copulation with motivation characteristic of normal sexual behavior.

The same stimulation intensities which elicited copulation were also suitable for self-stimulation. Response rates in daily 10-minute sessions were 50 to 75 presses per minute.

Self-stimulation was sometimes accompanied by a penile discharge containing motile sperm. Five of the ten rats ejected seminal plugs. This usually occurred several seconds after deactivation of the self-stimulation lever. One of the rats exhibited ejaculation on ten different occasions. Penile erection was usually absent during self-stimulation, and neither pelvic thrusts nor the customary post-ejaculatory posture ever occurred in the absence of a female.

Self-stimulation varied positively with the androgen level. To date, two of the rats have been given daily injections of 50 μg of testosterone propionate in oil for 7 days. The self-stimulation rate during the 7 days of injection was compared with the 7-day base line immediately preceding the injections. Such comparison showed that self-stimulation increased 17 percent for one rat and 37 percent for the other rat. After 1 month of self-stimulation tests with no androgen injections (to reestablish the baseline rate) the test was repeated on the first animal. Self-stimulation again increased significantly—this time 23 percent. All increases were statistically significant ($P < .01$). This is similar to Herberg's result (*5*).

	MOUNTS	INTROMISSIONS	EJACULATIONS
STIM. ON	30 (13-61)	18 (7-44)	2 (1-4)
STIM. OFF	1 (0-5)	1 (0-3)	0 (0)

Fig. 2. Control of copulatory behavior by electrical stimulation of the posterior hypothalamus of male rats. Mean values are based on the last 30 minutes of one test session for each of ten rats. Sessions lasted 30 to 75 minutes. Range of individual scores are in parentheses.

Histological examination of the brains revealed that the electrode tips had been in the medial forebrain bundle, just lateral to the fornix at the level of the premammillary nuclei in the posterior hypothalamus.

Thus, self-stimulation in the posterior hypothalamus is related to motivated sexual behavior. Electrical stimulation, like sexual stimulation, heightens sexual excitability to the point of copulation and orgasm and reinforces behavior leading to the stimulus. Therefore neural activity in the posterior hypothalamus may be normally involved in generating the excitement and reward of copulation.

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High-Pressure Reactions and Shear Strength of Serpentinized Dunite

Abstract. *The recently reported pronounced decrease in shear strength of serpentine-bearing rocks at 30 to 40 kilobars in the temperature range 300° to 520°C may be attributed to the transformation of serpentine to a pressure-dependent, 10-angstrom, 2:1 layer silicate plus brucite and periclase. This reaction increases density by about 8.5 percent.*

Riecker and Rooney's (*1*) experimental data show that the shear strength of serpentinite, and of dunite containing about 5 percent serpentine, decreases markedly as the temperature rises from 300° to 520°C under pressures of 30 kb or greater. They concluded that weakening is caused by dehydration of the serpentine. Our recent experimental work (*2*) on the stability of serpentine at high pressure

and temperature suggests a different explanation.

As Riecker and Rooney pointed out, their data below 30 kb showed only the normal inverse relation between strength and temperature; that is, isobaric sections at 10 and 20 kb showed an almost-linear decrease in shear strength with increasing temperature between 27° and 900°C. At 30 kb and higher, however, the data showed abrupt decrease in shear strength in the range 300° to 520°C, although in the range 520° to 900°C the shear strength again decreased linearly with increasing temperature.

We have demonstrated experimentally that at pressures exceeding 30 kb the stability field of serpentine in the temperature range 350° to 550°C is preempted by a pressure-dependent, oxonium-bearing, 2:1 layer silicate with a basal spacing of 10 Å and the composition $[(H_3O)_2Mg_5\square_1Si_8O_{20}(OH)_4]$ (*2*). The 10-Å phase occupies a large volume of P-T-X space in the system $MgO\text{-}SiO_2\text{-}H_2O$ and is stable to at least 90 kb below 550°C. Above 550°C under pressures greater than 30 kb it breaks down to the assemblage clinoenstatite-coesite-vapor. The phase-equilibrium diagram for the system $MgO\text{-}SiO_2\text{-}H_2O$ indicates that at or above 30 kb and below 550°C the serpentine in serpentinite or serpentinitized dunite would react as follows:

$$2[\underset{\substack{\text{serpentine}\\ d \simeq 2.55\ \text{g/cm}^3}}{Mg_6Si_4O_{10}(OH)_8}] \rightarrow \underset{\substack{\text{10-Å phase}\\ d \simeq 2.65\ \text{g/cm}^3}}{[(H_3O)_2Mg_5\square_1Si_8O_{20}(OH)_4]} + \underset{\substack{\text{brucite}\\ d = 2.37\ \text{g/cm}^3}}{3Mg(OH)_2} + \underset{\substack{\text{periclase}\\ d = 3.58\ \text{g/cm}^3}}{4MgO}$$

This reaction involves a $-\Delta v$ of about 12 to 16 cm³/mole and a corresponding density increase relative to serpentine of about 7.5 to 9.5 percent; it would result in development of new micropores and in nucleation and growth of a soft, slippery, low-strength, micaceous phase along preexisting grain boundaries in the serpentine. These changes would probably be manifested by a sudden decrease in apparent shear strength of the rock.

One should note that experimental work by us and by others (*3*) shows that serpentine is stable under between 20 and 30 kb below 550°C, and experimental studies in the low-pressure range (0.1 to 3 kb) show conclusively that it is stable at up to 500°C (*4–6*). It has also been demonstrated experimentally that aluminous serpentine of clinochlore composition $[Mg_5Al_2Si_3O_{10}(OH)_8]$ is stable at least to 500°C, and possibly to 600°C, under pressures up to 20 kb (*7*). It seems improbable, therefore, that the strength of serpentine-bearing rocks under high pressure would be reduced significantly in the temperature range 300° to 520°C as a result of serpentine dehydration, as concluded by Riecker and Rooney.

As we have noted, the reported shear-strength data for serpentinized dunite under 30 and 40 kb show a "normal" regular decrease with increasing temperature between 520° and 900°C. At or above about 550°C, the 10 Å phase–brucite periclase assemblage would ultimately transform to the assemblage forsterite-clinoenstatite-vapor in accord with the two reactions:

$$[(H_3O)_2Mg_5\square_1Si_8O_{20}(OH)_4] + 3Mg(OH)_2 + 4MgO \rightarrow 8MgSiO_3 + 4Mg(OH)_2 + 4H_2O$$

$$8MgSiO_3 + 4Mg(OH)_2 + 4H_2O \rightarrow 4Mg_2SiO_4 + 4MgSiO_3 + 8H_2O$$

Our experimental results to date suggest that these reactions are essentially independent of pressure above 30 kb $[(dt/dp) > 30\ \text{kb} \simeq 0]$, in accord with the pressure independence of the dehydration temperature of serpentine under pressures below 30 kb (*3, 4, 6*). If one assumes that the vapor phase is contained in the sample, the volume change associated with the development of the assemblage forsterite-clinoenstatite-vapor is very small if not essentially zero, and the density of the vapor phase is about 1.30 g/cm³ based on the zero-pressure densities of the solid phases. By comparison, the values for the density of water on the 500°C isotherm at 30, 40, and 50 kb, based on shock-wave measurements, are 1.27, 1.34, and 1.40 g/cm³, respectively (*8*). Thus, if the vapor phase were retained, the development of forsterite and clinoenstatite would not be attended by any significant volume change, and a "normal" inverse relation between shear strength and temperature would be observed; this is exactly what the data of Riecker and Rooney show.

Experimental results of Raleigh and Paterson (*9*) show that serpentinite undergoes both weakening and embrittlement above 500° to 600°C under pressures as high as 5 kb, which changes they correlate with the dehydration of serpentine. The specific mechanisms invoked are (i) reduction of effective confining pressure, due to the pore pressure of the water released on dehydration, and (ii) loss in cohesive strength because of the development of talc and forsterite, at the expense of serpentine, along preexisting grain boundaries according to the reaction:

$$5[Mg_6Si_4O_{10}(OH)_8] \rightarrow 12Mg_2SiO_4 + Mg_6Si_8O_{20}(OH)_4 + 18H_2O$$

Raleigh and Paterson point out that their results do not enable assessment of the relative importance of these mechanisms. At pressures exceeding 30 kb, however, the development of the assemblage 10 Å phase–brucite periclase from serpentine, without the presence of water as a free phase, at temperatures below 550°C strongly suggests that the second type of mechanism (neomineralization) is operative at the high pressures employed by Riecker and Rooney. Furthermore, the results of these workers show no significant weakening of serpentinized dunite under pressures exceeding 30 kb between 520° and 900°C, in which temperature range water is a free phase in association with forsterite and clinoenstatite; the pore-pressure mechanism of Raleigh and Paterson may not be operative under pressures exceeding 30 kb.

Careful postmortem study of the phase composition and microtexture of experimental products from high-pressure shear tests on serpentine-bearing rocks, with particular reference to occurrence of the 10-Å phase, should provide considerable insight into the weakening phenomenon.

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In discussing our paper (*1*) Sclar and Carrison (*2*) postulate an interesting alternative mechanism to explain weakening of experimentally deformed minerals and rocks in the presence of water. For various reasons we do not believe that this mechanism operates to any significant extent in our shearing tests.

They contend that shear weakening of the serpentinite and serpentinized dunite occurs *abruptly* above 30 kb in the temperature range 300 to 520°C, where the stability field of serpentine is preempted by a 10 Å layer–silicate phase. Although more pronounced at 30 kb, weakening is not abrupt, but occurs at pressures well below 30 kb. At 15 kb (*1*, Fig. 2) the strength of unserpentinized dunite and synthetic forsterite is greater than the strength of serpentinized dunite. The specimen is more tightly confined at higher pressures, which fact explains the apparent increase in weakening.

We did not specify the dehydration temperature of the serpentine, but, as we stated, those pellets sheared above 450°C were damp after removal from the press. The x-ray patterns also show that the serpentine begins to break down near 500°C. It is notable that Handin (*3*) found weakening in serpentine at temperatures as low as 200°C. Unfortunately, it is not known what effect the composition of the serpentine has on dehydration temperature in our tests; nor do we know which serpentine minerals are present in the samples.

Lastly, the funerary suggestions of Sclar and Carrison were fulfilled: postmortem studies were made of more than 130 sheared pellets shortly after each test was completed; studies included a thorough x-ray examination, using diffractometer and film methods as well as microscopic observations. No brucite, periclase, or 10 Å layer–silicate phase were identified at any pressure, temperature, or shearing condition attained in the tests. Since receipt of Sclar and Carrison's rebuttal (*2*), we have made other, longer-time tests (45 minutes) on serpentinite in the region above 30 kb at 450°C. The x-ray patterns did not show a 10-Å phase. Since most of our shearing tests were accomplished rapidly, usually within 10 minutes, we think it unlikely that sufficient time would be available for nucleation and growth of a new phase. It may be important in this respect that Sclar and Carrison used reactive oxide mixtures in their experiments, while our starting materials were natural or synthetic minerals.

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Single Cells, Coconut Milk, and Embryogenesis in vitro

Steward and his co-workers (*1*) reported obtaining thousands of embryos from carrot cell suspensions grown in media containing coconut milk. This fact was taken as evidence for his hypothesis (*2*) that isolated cells tended to behave as if they were zygotes when exposed to media containing coconut milk (the liquid endosperm that normally nourishes the coconut embryo). The belief that coconut milk has embryogenic effects on single plant cells in culture has now achieved the status of accepted truth. Perhaps the final approbation has been given this theory in *Plant Biochemistry* by Bonner and Varner (*3*). Bonner states, "Two conditions must be satisfied for this to occur [embryogenesis]. The specialized cell must be separated from its neighbors, that is, it must be a single cell. In addition, the cell must be surrounded by medium which contains the nutrients needed for embryo growth. The liquid endosperm of coconut or horse chestnut contains the required substances. If either of the two conditions is not satisfied, embryos are not produced. Thus, if clumps of cells, rather than single isolated cells, are placed in the enriched medium, they grow into undifferentiated masses of callus. If the embryonic nutrients [coconut milk, and such] are omitted, no growth takes place."

The categorical statements made by Bonner are surprising, to say the least, since Steward's theory has never been supported by experiments showing that coconut milk has the purported effect, or that the embryos in cell cultures must be derived from single cells. In fact, it has been shown conclusively that neither coconut milk nor any other similar nutrient complex is required for embryogenesis in carrot cell cultures (*4, 5*), and the available evidence indicates that embryos in cultures of carrot and other species usually develop from cell clumps—not from single cells (*6, 7*).

I offer the following points to support this contention:

1) Although Steward has obtained embryos from cell suspensions of the wild carrot, *Daucus carota*, grown on media containing coconut milk (*1*), he has not reported control experiments establishing that coconut milk is the component of the medium responsible for embryogenesis. Steward's data which showed an absence of cell division in the absence of coconut milk (*1*) hardly comprised an adequate control, since the basal medium used was designed 30 years earlier for growing tomato root cultures (*8*) and has too little of nitrogen and several other minerals for adequate growth. Experiments of others show that embryogenesis occurs readily in wild carrot cultures started and maintained through numerous transfers on media containing only minerals, sucrose, vitamins, and an auxin (*4, 5, 7*). If there are special "embryonic nutrients" involved, they must be produced by the cells themselves, a fact that has theoretical implications different from those of Steward's theory.

2) In cultures of other varieties of carrot (*9*) and in other species (*10*) where embryos have occasionally been observed, either coconut milk was absent from the medium or the essential components of the medium were not identified by control experiments. In short, although coconut milk has an unusual capacity for inducing growth in explants and is often used in culture media, it has never been shown to have any relevance for embryogenesis in vitro. On the contrary, in the only well-studied experimental system, the wild carrot, coconut milk has been shown to inhibit embryogenesis partially or completely, depending on the cultural circumstances (*4, 5, 7*). Abnormal development of young embryos in the presence of autoclaved coconut milk was demonstrated by Van Overbeek in 1942 (*11*).

3) Steward has not provided data to support this contention that single cells were the source of embryos in his cultures. The available evidence indicates that mitosis in plant cell suspensions