tive area, and it is here that we see the pivotal role played by estrogen. Pfaff shows how estrogen increases biosynthetic and secretory activity of cells in the ventromedial hypothalamus and increases electrical excitability of medial anterior and basal hypothalamic neurons. Lesions in the medial anterior hypothalamus and ventromedial nucleus (VMN) of the hypothalamus result in severe deficits in lordosis behavior. This effect is transitory, however, indicating that these cells are not part of a direct reflex arc but influence the descending brainstem pathways that facilitate lordosis. In complementary studies, electrical stimulation of the VMN facilitates lordosis in estrogen-primed, ovariectomized females. Interestingly, estrogen treatment decreases electrical activity of POA neurons and lordosis performance is increased following POA lesions but is inhibited when the POA is stimulated. These apposing actions of the VMN and the POA serve to regulate female sexual receptivity.

Pfaff next traces the neuronal projections from the VMN and POA to the mesencephalic central gray, describing how axons descend through the hypothalamus and medial forebrain bundle in layers. Electrical stimulation of this area facilitates lordosis behavior whereas lesions abolish it. Descending fibers exit the central gray, projecting to the reticular formation of the lower brainstem. The hormone-dependent hypothalamic output signals that are transformed and relayed in the central gray are carried in the lateral vestibulospinal and reticulospinal tracts, terminating in the spinal cord. Lesions of these descending pathways disrupt lordosis behavior whereas stimulation of the lateral vestibular nucleus, the source of the lateral vestibulospinal tract, facilitates it. The final common pathway, the motoneurons controlling the muscles responsible for elevating the rump, the most crucial component of the lordosis behavior, is located in the medial and ventral borders of the ventral horn.

This analysis of the neural circuitry of lordosis behavior, which forms the major portion of the book, is followed by a discussion of its implications for neuroscience and related fields of behavioral research. Though providing much insight for the former, Pfaff is not always successful as he moves outside the boundaries of the neural control of behavior. He relies on dated ethological concepts, such as Lorenz's hydraulic model, and ignores recent advances in behavioral biology. Another disappointment is the lack of incorporation of relevant research from other laboratories. Although a plausible theory of the central mechanisms that differentiate male from female sexual behavior is presented, there is no consideration of sex differences in brain structure and function.

These are minor complaints, however. *Estrogens and Brain Function* is a well-written and authoritative account of one of the outstanding research programs in neuroscience. It undoubtedly will be a model for future analyses of the physiological mechanisms of motivation.

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The Biophysical Substrate

Molluscan Nerve Cells. From Biophysics to Behavior. Papers from a meeting, Cold Spring Harbor, N.Y., May 1980. JOHN KOESTER and JOHN H. BYRNE, Eds. Cold Spring Harbor Laboratory, Cold Spring Harbor, N.Y., 1980. xx, 230 pp., illus. $26. Cold Spring Harbor Reports in the Neurosciences, vol. 1.

In the study of the physiology of excitable (nerve and muscle) membranes a quiet revolution has taken place in the last five years. The conductances through which membrane currents flow have been shown in some cases to be quantized, or made up of irreducible units of 2 to 30 picosiemens. These conductance steps represent the opening and closing, many times per second, of single ionic channels whose molecular properties are just beginning to be understood. In addition, the roles of intracellular calcium and hydrogen ions are being actively studied, and both are proving to have strong effects on cellular function. Some recently discovered potassium currents are strongly implicated in the process of rhythmical firing and "burst" or grouped discharges, and these and some calcium currents affect the control of some simple behaviors. All of these topics are covered in this delightful new collection of brief reports.

The book is made up of transcriptions of talks given at a meeting organized by C. F. Stevens and E. Kandel. One purpose of the meeting was to stimulate interaction between investigators of membrane biophysics and of neural control of behavior. The rationale for this was that "it is now possible to relate the biophysical properties of individual neurons to the features of the behavior that they mediate." Whether the organizers' goal was in fact reached is dubious, but the reports are concise and informative and cover the latest developments in each subdiscipline. Most of the work described was done on molluscan neurons, which are generally spheroidal and large (100 microns or more in diameter) and which survive well in vitro and tolerate multiple impalements with microelectrodes.

The foreword by J. D. Watson contains an absorbing history of the neuroscience programs at Cold Spring Harbor Laboratory. These include important meetings on neurons in 1952, at which the Hodgkin-Huxley model of excitation was widely discussed, on sensory receptors in 1965, and on synapses in 1975, all resulting in well-organized and important contributions to the literature. A historical chapter by Kandel places the recent work in context, and Stevens attempts the feat of reviewing all the techniques used in the present studies in 21 pages, without illustrations (which he does with some success). The book is not for the completely uninitiated, however.

The biophysical material, 17 of the 19 reports, is presented in accessible chunks seven to ten pages in length. These give the news but do not overtax. A general summary of properties of calcium channels (Hagiwara) contains a caveat for the use of preparations such as barnacle and heart muscle or presynaptic terminals where perfect space-clamp of membrane potential is not possible but where important information can be obtained under appropriate conditions. The inactivation of calcium channels by accumulation of intracellular calcium is documented in a sparkingly clear way (Tillotson). The single-channel conductance of calcium channels is shown to be much lower than that of sodium or potassium channels, perhaps as little as 0.2 picosiemens (Brown). A probabilistic model of calcium currents in presynaptic terminals (Llinás) gives a good representation of pre- and postsynaptic events in the squid giant synapse. The interactions of sodium, potassium, and hydrogen ions are such that nerve cells placed in sodium-free solutions will be less able to regulate their intracellular *p*H (Thomas). Calcium buffers in squid axons can bind 99.95 percent of an artificially introduced calcium load (Brinley). A potassium conductance that is activated by elevations of intracellular calcium is discussed with respect to which divalent ions stimulate it most strongly (Meech) and how it is affected by membrane potential (Lux). Some updated models are presented for calcium regulation (S. Smith), potassi-

um-channel inactivation (Thompson), repetitive firing (Connor), and burst production (T. Smith, Gorman *et al.*). Neurons in cerebellar and brainstem slices are shown to have action potentials that differ substantively from those of axons (Llinás). A densely packed report on acetylcholine-activated channels in snail neurons (Marty) includes an Eyring model that can explain the effects of blocking ions. A slow inhibitory input can abolish the negative resistance characteristic of an *Aplysia* neuron (Wilson), as can the application of dopamine. One report (Shapiro) shows great persistence in trying to apply voltage-clamp analysis to nerve terminals that are clearly not under potential control.

The two papers on behavior are convincing if not earthshaking. The secretion of ink by a specialized gland in *Aplysia* occurs only when the appropriate motor neurons are excited. Thus "inking" may be taken as the end point of a reflex arc that includes sensory neurons. That motor neurons do not fire action potentials until 1 to 2 seconds after the start of a stimulus and that inking is similarly retarded are explainable by a strong early outward potassium current. Hence, "biophysics explains behavior" (Byrne and Koester). Another behavior in *Aplysia*, the gill-withdrawal reflex, exhibits habituation, or a decrease in amplitude with repetition, and sensitization, or a restoration of amplitude with a certain novel type of stimulus. The first may be explained by an inactivation of inward calcium current in the presynaptic terminals, and the second by a decreased potassium current (Klein). (A persistent quibble: At a meeting intended to bring biophysicists and behaviorists together, where were Davis, who has so carefully dissected the neural basis of classical conditioning in *Pleurobranchaea*, Willows, who has extensively studied the motor control of swimming and feeding in *Tritonia*, or Kater, who has similarly analyzed feeding in *Helisoma*?)

I did not find any typographical errors, but Llinás's given name is misspelled throughout. Much credit should go to the editors and their graduate-student "scribes" for a carefully produced book with an even level of discussion. The book should be welcomed by all who work in the field, who may happily look forward to further Cold Spring Harbor Reports in the Neurosciences, of which this is the first.

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Nutrition During Pregnancy

Diet in Pregnancy. A Randomized Controlled Trial of Nutritional Supplements. DAVID RUSH, ZENA STEIN, and MERVYN SUSSER. Liss, New York, 1980. xxviii, 200 pp. $26. Birth Defects: Original Article Series, Vol. 16, No. 3.

In the early 1970's research on dietary factors that influence pregnancy outcome took a new direction. The large body of evidence from previous epidemiological studies was mixed concerning the likelihood that nutritional intervention during pregnancy would substantially improve fetal growth and reduce perinatal mortality. Studies conducted in the United States and England suggested that nutritional supplementation during pregnancy would have no effect. Studies from developing countries, although inconclusive, suggested that further research was warranted. The questions that had to be addressed dealt with the efficacy of specific types of nutritional intervention. At that time protein deficiency was considered by most authorities to be the major nutritional problem of the developing nations. Therefore, most of that generation of nutrition intervention studies focused on the efficacy of providing a protein supplement to the normal diets of pregnant women. In most cases an increase in birthweight was to be the measure of the success of the supplementation. Though the focus of these intervention trials was the developing countries, Rush, Stein, Susser, and colleagues conducted such a study in what they considered to be a high-risk population of poor black women from New York City. This book is a description of that study, bringing together in one place the study rationale, design, and results, a summary version of which has been published in *Pediatrics* (vol. 65, April 1980). The authors' justification for publishing the work in book form stems from the controversial nature of their results, interpretation, and conclusions, the most important being the failure of the intervention to raise birthweight.

The objective of the study was to improve the prenatal and early-postnatal development of offspring by supplementing maternal diets with protein during pregnancy. The experiment called for a randomized controlled trial of two liquid nutritional supplements, administered as either a high-protein (40 grams per day), high-energy (470 kilocalories per day) "supplement" beverage or a similar "complement" beverage with very little protein (6 grams per day) and slightly less energy (322 kilocalories per day). Controls received multivitamin-mineral tablets that were similar in composition to the vitamin-mineral component of the liquid supplements. The study did not confirm the hypothesis that provision of a nutritional supplement during pregnancy will increase birthweight.

The authors report no significant benefit of either protein or caloric supplements in elevating birthweights above those for the control group. The only significant effects on birthweight were observed in the offspring of a subsample of smoking mothers who received the supplement or the complement. In addition, mothers who received the supplement delivered infants who at one year of age scored better on three of ten behavioral tests.

Given that past analyses of the efficacy of nutritional supplements have generally led to the conclusion that birthweight can be increased in the offspring of women who truly are malnourished, the authors' conclusion that the women they studied were generally not sufficiently malnourished to benefit from a protein supplement is probably correct. It is unfortunate that this possibility was not recognized earlier. The authors' evaluation of the protein intake of the population prior to the study was based on data obtained from 24-hour dietary recalls. Since underreporting of intakes of all nutrients by this method is common, the data on protein intake should have been evaluated relative to data on total caloric intake. A diet in which protein accounts for less than 12 percent of the total caloric intake is widely accepted as indicative of protein deficiency, and by this criterion the population in question would not be considered deficient. When the diets of the study subjects at recruitment were analyzed from 24-hour recalls, the average protein intake of each of the three groups was higher than previously reported values for the population under study, with the 61 to 69 grams of protein ingested per day accounting for about 14.5 percent of the total calories ingested (1700 to 1900 kilocalories). (The 24-hour recalls were also used to screen individual prospective subjects for a history of low protein intake and therefore at risk of bearing children with low birthweight, although a single 24-hour recall should not be used to evaluate diet histories for individuals.)

If it was not evident before the study