The Importance of Feminist Critique for Contemporary Cell Biology

THE BIOLOGY AND GENDER STUDY GROUP
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Biology is seen not merely as a privileged oppressor of women but as a co-victim of masculinist social assumptions. We see feminist critique as one of the normative controls that any scientist must perform whenever analyzing data, and we seek to demonstrate what has happened when this control has not been utilized. Narratives of fertilization and sex determination traditionally have been modeled on the cultural patterns of male/female interaction, leading to gender associations being placed on cells and their components. We also find that when gender biases are controlled, new perceptions of these intracellular and extracellular relationships emerge.

Nancy Tuana (this volume) has traced the seed-and-soil analogy from cosmological myths through Aristotle into the biology of the 1700s. Modeling his embryology after his social ideal, Aristotle promulgated the notions of male activity versus female passivity, the female as incomplete male, and the male as the real parent of the offspring. The female merely provided passive matter to be molded by the male sperm. While there were competing views of embryology during Aristotle's time, Aristotle's principles got the support of St. Thomas and were given the sanction of both religion and scientific philosophy (Horowitz 1976, 183). In this essay, we will attempt to show that this myth is still found in the core of modern biology and that various "revisionist" theories have been proposed within the past five years to offset this myth.

We have come to look at feminist critique as we would any other experimental control. Whenever one performs an experiment, one sets up all the controls one can think of in order to make as certain as possible that the result obtained does not come from any other source. One asks oneself what assumptions one is making. Have I assumed the temperature to be constant? Have I assumed that the pH doesn't change over the time of the reaction? Feminist critique asks if there may be some assumptions that we haven't checked concerning gender bias. In this way feminist critique should

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be part of normative science. Like any control, it seeks to provide critical rigor, and to ignore this critique is to ignore a possible source of error.

The following essay is not an attempt to redress past injustices which biology has inflicted upon women. This task has been done by several excellent volumes that have recently been published (Sayers 1982; Bleier 1984, 1986; Fausto-Sterling 1985). Rather, this paper focuses on what feminist critique can do to strengthen biology. What emerges is that gender biases do inform several areas of modern biology and that these biases have been detrimental to the discipline. In other words, whereas most feminist studies of biology portray it—with some justice—as a privileged oppressor, biology has also been a victim of the cultural norms. These masculinist assumptions have impoverished biology by causing us to focus on certain problems to the exclusion of others, and they have led us to make particular interpretations when equally valid alternatives were available.

Sperm Goes A'Courtin'

If Aristotle modeled fertilization and sex determination on the social principles of his time, he had plenty of company among more contemporary biologists. The first major physiological model of sex determination was proposed in 1890 when Sir Patrick Geddes and J. Arthur Thomson published *The Evolution of Sex*, one of the first popular treatises on sexual physiology. By then, it had been established that fertilization was the result of the union of sperm and egg. But still unanswered was the mechanism by which this event constructed the embryo. One of the central problems addressed by this highly praised volume was how sex was determined. Their theory was that there were two types of metabolism: *anabolism*, the storing up of energy, and *katabolism*, the utilization of stored energy. The determination of sexual characteristics depended on which mode of metabolism prevailed. "In the determination of sex, influences favoring katabolism tend to result in the production of males, as those favoring anabolism similarly increase the production of females" (Geddes and Thomson 1890, 45, 267). This conclusion was confirmed by looking at the katabolic behavior of adult males (shorter life span, greater activity and smaller size) compared to the energy-conserving habits of females who they described as "larger, more passive, vegetative, and conservative."[1] In a later revision (1914, 205-206) they would say, "We may speak of women's constitution and temper as more conservative, of man's more unstable. . . . We regard the woman as being more anabolic, man as relatively katabolic; and whether this biological hypothesis be a good one or not, it certainly does no social harm."

This microcosm/macrocosm relationship between female animals and their nutritive, passive eggs and between male animals and their mobile, vigorous sperm was not accidental. Geddes and Thomson viewed the sperm and egg

as representing two divergent forms of metabolism established by protozoan organisms, and "what was decided among the prehistoric protozoa cannot be annulled by Act of Parliament." Furthermore, as in Aristotle, the difference between the two is nutrition. The motivating force impelling the sperm towards the egg was hunger. The yolk-laden egg was seen as being pursued by hungry sperm seeking their nourishment. The Aristotelian notion of activity and passivity is again linked with the role of female as nutrient provider. It is also linked with that most masculine of British rituals, the hunt.[2]

It is usually assumed that the discovery of the X and Y sex chromosomes put an end to these environmental theories of sex determination. This is today's interpretation and not that of their discoverer. What the genetics texts do not tell us is that C.E. McClung placed his observations of sex chromosomes directly in the context of Geddes and Thomson's environmental model. Using a courtship analogy wherein the many spermatic suitors courted the egg in its ovarian parlour, McClung (1901, 224) stated that the egg "is able to attract that form of spermatozoon which will produce an individual of the sex most desirable to the welfare of the species." He then goes on to provide an explicit gender-laden correlation of the germ cells mirroring the behavior of the sexual animals that produced them:

> The ovum determines which sort of sperm shall be allowed entrance into the egg substance. In this we see the extension, to its ultimate limit, of the well-known role of selection on the part of the female organism. The ovum is thus placed in a delicate adjustment with regard to the surrounding conditions and reacts in a way to best subserve the interests of the species. To it come two forms of spermatozoa from which selection is made in response to environmental necessities. Adverse conditions demand a preponderance of males, unusually favorable conditions induce an excess of females, while normal environments apportion an approximately equal representation of the sexes. (McClung 1902,76)

McClung concluded this paper by quoting that Geddes and Thomson's theory of anabolism and katabolism provided the best explanation as to whether the germ cells would eventually grow into "passive yolk-laden ova or into minute mobile spermatozoa."

The Sperm Saga

Courtship is only one of the narrative structures used to describe fertilization. Indeed, "sperm tales" make a fascinating subgenre of science fiction. One of the major classes of sperm stories portrays the sperm as a heroic victor. In these narratives, the egg doesn't choose a suitor. Rather, the egg is the

passive prize awarded to the victor. This epic of the heroic sperm struggling against the hostile uterus is the account of fertilization usually seen in contemporary introductory biology texts. The following is from one of this decade's best introductory textbooks.

> Immediately, the question of the fertile life of the sperm in the reproductive tract becomes apparent. We have said that one ejaculation releases about 100 million sperm into the vagina. Conditions in the vagina are very inhospitable to sperm, and vast numbers are killed before they have a chance to pass into the cervix. Millions of others die or become infertile in the uterus or oviducts, and millions more go up the wrong oviduct or never find their way into an oviduct at all. The journey to the upper portion of the oviducts is an extremely long and hazardous one for objects so tiny. . . . Only one of the millions of sperm cells released into the vagina actually penetrates the egg cell and fertilizes it. As soon as that one cell has fertilized the egg, the [egg] cell membrane becomes impenetrable to other sperm cells, which soon die. (Keeton 1976,394)

We might end the saga by announcing, "I alone am saved." These sperm stories are variants of the heroic quest myths such as the Odyssey or the Aeneid. Like Aeneas, the spermatic hero survives challenges in his journey to a new land, defeats his rivals, marries the princess and starts a new society. The sperm tale is a myth of our origin. The founder of our body is the noble survivor of an immense struggle who deserved the egg as his reward. It is a thrilling and self-congratulatory story.

The details of these fertilization narratives fit perfectly into Campbell's archetype of such myths. Campbell (1956,387), however, believes that "there is no hiding place for the gods from the searching telescope or microscope." In this he has been wrong. The myth lies embedded within microscopic science.[3]

The next passage comes from a book to be given expectant mothers. It, too, starts with the heroic sperm model but then ventures off into more disturbing images.

> Spermatozoa swim with a quick vibratory motion. . . . In ascending the uterus and Fallopian tube they must swim against the same current that waft the ovum downward. . . . Although a million spermatozoa die in the vagina as a result of the acid secretions there, myriads survive, penetrate the neck of the uterus and swarm up through the uterine cavity and into the Fallopian tube. *There they lie in wait for the ovum.* As soon as the ovum comes near the *army of spermatozoa*, the latter, as

> if they *were tiny bits of steel drawn by a powerful magnet, fly at the ovum*. One *penetrates*, but only one. . . . *As soon as the one enters, the door is shut on other suitors*. Now, as if *electrified*, all the particles of the ovum (now fused with the sperm) exhibit vigorous agitation. (Russell 1977, 24, emphasis added)

In one image we see the fertilization as a kind of martial gang-rape, the members of the masculine army lying in wait for the passive egg. In another image, the egg is a whore, attracting the soldiers like a magnet, the classical seduction image and rationale for rape. The egg obviously wanted it. Yet, once *penetrated*, the egg becomes the virtuous lady, closing its door to the other *suitors*. Only then is the egg, because it has fused with a sperm, rescued from dormancy and becomes active. The fertilizing sperm is a hero who survives while others perish, a soldier, a shard of steel, a successful suitor, and the cause of movement in the egg. The ovum is a passive victim, a whore and finally, a proper lady whose fulfillment is attained.

The accounts in such textbooks must seem pretty convincing to an outsider. The following is from a paper on the history of conception theories, published—by a philosopher—in 1984.

> Aristotle's intuitions about the male as trigger which begins an epigenetic process is a foreshadowing of modern biological theory in which the sperm is the active agent that must move and penetrate the ovum. The egg passively awaits the sperm, which only contributes a nucleus, whereas the egg contributes all the cytoplasmic structures (along with its nucleus) to the zygote. In other words, the egg contributes the material and the form, and the sperm contributes the activating agent and the form. . . . Thus even modern biology recognizes the specialized and differentiated roles of male and female in an account of conception. Aristotle's move in such a direction was indeed farsighted. (Boylan 1984, 110)

Energetic Eggs and Active Anlagen

Until very recently, textbook accounts have emphasized (even idealized) the passivity of the egg. The notion of the male semen "awakening the slumbering egg" is seen as early as 1795 (Reil 1795, 79), and this idea, according to historian Tim Lenoir (1982, 37) "was to have an illustrious future." Since 1980, however, there has been a new account of sperm-egg interactions. This revisionism has been spurred on by new data (and new interpretations of old data) which has forced a re-examination of the accepted scenario. The egg appears to be less a "silent partner" and more an energetic participant in fertilization. Two of the major investigators forcing this re-evaluation are

Gerald and Heide Schatten. Using scanning electron microscopy, they discovered that when the sperm contacts the egg, it does not burrow through.[4] Rather, the egg directs the growth of microvilli—small finger-like projections of the cell surface—to clasp the sperm and slowly draw it into the cell. The mound of microvilli extending to the sperm had been known since 1895 when E.B. Wilson published the first photo-graphs of sea urchin fertilization. But this structure has been largely ignored until the recent studies, and its role is still controversial.

In 1983, the Schattens wrote a review article for laypeople on fertilization. Entitled "The Energetic Egg," it consciously sought to change the metaphors by which fertilization is thought about and taught.

> In the past years, investigations of the curious cone that Wilson recorded have led to a new view of the roles that sperm and egg play in their dramatic meeting. The classic account, current for centuries, has emphasized the sperm's performance and relegated to the egg the supporting role of Sleeping Beauty—a dormant bride awaiting her mate's magic kiss, which instills the spirit that brings her to life. The egg is central to this drama, to be sure, but it is as passive a character as the Grimm brothers' princess. Now, it is becoming clear that the egg is not merely a large yolk-filled sphere into which the sperm burrows to endow new life. Rather, recent research suggest the almost heretical view that sperm and egg are mutually active partners. (Schatten and Schatten 1983,29)

Other studies are showing this mutual activity in other ways. In mammals, the female reproductive tract is being seen as more than a passive or even hostile conduit through which sperm are tested before they can reach the egg. Freshly ejaculated mammalian sperm are not normally able to fertilize the eggs in many species. They have to become *capacitated.* This capacitation appears to be mediated through secretions of the female genital tract. Furthermore, upon reaching the egg, mammalian sperm release enzymes which digest some of the extracellular vestments which surround the egg. These released enzymes, however, are not active. They become activated by interacting with another secretion of the female reproductive tract. Thus, neither the egg nor the female reproductive tract is a passive element in fertilization. The sperm and the egg are both active agents and passive substrates. "Ever since the invention of the light microscope, researchers have marveled at the energy and endurance of the sperm in its journey to the egg. Now, with the aid of the electron microscope, we can wonder equally at the speed and enterprise of the egg, as it clasps the sperm and guides its nucleus to the center" (Schatten and Schatten 1983, 34).

As we have seen above, the determination of maleness and femaleness has

also been inscribed by concepts of active masculinity and passive femaleness. (This means that *sex*, not just *gender*, can be socially constructed!) Indeed, until 1986, all modern biological theories of mammalian sex determination have assumed that the female condition is developed passively, while the male condition is actively produced from the otherwise female state (for review, see Gilbert 1985, 643). This has been based largely on Jost's experiments where rabbits developed the female body condition when their gonadal rudiments were removed before they had differentiated into testes or ovaries. But these experiments actually dealt with the generation of secondary sexual characteristics and not the primary sex determination event—the differentiation of the sexually indifferent gonadal primordia into ovaries or testes.

During the past four years, these theories of primary sex differentiation (notably the H-Y antigen model wherein male cells synthesized a factor absent in female cells which caused the gonadal primordia to become testes) have been criticized by several scientists, and a new hypothesis has been proposed by Eva Eicher and Linda Washburn of the Jackson Laboratory. This new model is based on extensive genetic evidence and incorporates data that could not be explained by the previous accounts of sex determination. In their introductory statement, Eicher and Washburn point out the active and passive contexts that have been ascribed to the development of the primary sexual organs. They put forth their hypotheses as a controlled corrective for traditional views.

> Some investigators have over-emphasized the hypothesis that the Y chromosome is involved in testis determination by presenting the induction of testicular tissue as an active (gene directed, dominant) event while presenting the induction of ovarian tissue as a passive (automatic) event. Certainly, the induction of ovarian tissue is as much an active, genetically directed developmental process as is the induction of testicular tissue or, for that matter, the induction of any cellular differentiation process. Almost nothing has been written about genes involved in the induction of ovarian tissue from the undifferentiated gonad. The genetics of testis determination is easier to study because human individuals with a Y chromosome and no testicular tissue or with no Y chromosome and testicular tissue, are relatively easy to identify. Nevertheless, speculation on the kind of gonadal tissue that would develop in an XX individual if ovarian tissue induction fails could provide criteria for identifying affected individuals and thus lead to the discovery of ovarian determination genes. (Eicher and Washburn 1986, 328)

Again, we see that alternative versions of long-held scientific "truths" can

be generated. A feminist critique of cellular and molecular biology does not necessarily mean a more intuitivistic approach. Rather, it involves being open to different interpretations of one's data and having the ability to ask questions that would not have occurred within the traditional context. The studies of Eicher and Washburn on sex determination and those of the Schattens on fertilization can be viewed as feminist-influenced critiques of cell and molecular biology. They have controlled for gender biases rather than let the ancient myth run uncontrolled through their interpretations. Yet the techniques used in their analyses are not different than those of other scientists working in their respective fields, and the approaches used in these studies are no "softer" than those used by researchers working within the traditional paradigms.[5]

A Nuclear Family: The Sexualization of the Cell

The sperm and egg are *gametes*; that is marriage partners. As we have seen, their interactions have been modeled on various courtship behaviors. This extrapolates, however, into a husband-wife arrangement in the zygote cell. It is again not surprising, then, to find this relationship reflected in the relationship between nucleus and cytoplasm. The sperm, after all, is viewed as a motile nucleus while the cytoplasm of the zygote and its descendants is derived entirely from the ovum (Morgan 1926, 45). One might argue that the ovum provides a nuclear component equal to that of the sperm, but this is usually overlooked (note the parentheses in the above quotation from Boylan). Even today among biologists, the term "maternal inheritance" is identical with "cytoplasmic inheritance." The nucleus came to be seen as the masculine ruler of the cell, the stable yet dynamic inheritance from former generations, the unmoved mover, the mind of the cell. The cytoplasm became the feminine body of the cell, the fluid, changeable, changing partner of the marriage.

This marriage trope was extremely prevalent during the 1930's when there were at least four competing views of the relationship between the cytoplasm and the nucleus (Gilbert, in press). What one finds is that the relationship of husband to wife becomes that of nucleus to cytoplasm. In Germany, one of the dominant theories modeled the cell after an autocratic Prussian family. The nucleus contained all the executive functions and the cytoplasm did whatever the nucleus commanded. Indeed, the cytoplasm existed only to be physically acted upon by the nuclear genes. As Harwood (1984, 3) has pointed out, defenders of this *Kernmonopol* wrote of the supremacy ("*Uberlegenheit*") of the genes and the dominating role of the nucleus ("*die dominierende Rolle des Kernes*"). The leading American geneticist, T.H. Morgan, modeled the cell after a more American family. First, the nucleus and the cytoplasm conferred; *then*, the nucleus told the cytoplasm what to do. The nucleus, like

the ideal American husband, still had the power and the final decision; but the decision was made only after discussions with the female partner. Not only was this a more American view of marriage, it was also the relationship between T.H. Morgan and his wife (G. Allen, Personal Communication). A third view came from C.H. Waddington, a British socialist. Waddington married a successful architect and viewed his marriage as a partnership. Werskey (1978, 221) has pointed out that Waddington respected women as intellectual equals, and Waddington viewed the marriage of nucleus and cytoplasm as a partnership. In *Organisers and Genes* (1940), Waddington tried to show the equality of nucleus and cytoplasm, neither dominating the other. His cell, like his notion of marriage, was a partnership between equals. The fourth view comes from the American Black embryologist E.E. Just (1939) who declared the cytoplasm to dominate over the nucleus. The nucleus was subservient to the commands given it by the cytoplasm, and only the cytoplasm was endowed with vitality. This also reflects Just's view of male/female relationships, for "Just saw himself working for Hedwig [his lover] as a slave works for his master" (Manning 1983, 265). For Just, who viewed fertilization largely as a consequence of the cytoplasmic activity of the egg, the male was subservient to the female. Thus, all four views of nuclear/cytoplasmic interactions reflect views of male/female interactions.

Contemporary biology, although aware of the interactions of the cytoplasm and nucleus, still tends to portray the nucleus as the head of the family's hierarchy. Jacob (1976, 224) writes, "Among all the constituents of living organisms, the genetic material has a privileged position. It occupies the summit of the pyramid and decides the properties of the organism. The other constituents are charged with the execution of the decision." The term "genetic engineering" (like "reproductive technology") is a masculine metaphor appropriating the role of procreation to technology. Haraway (1984) claims that "genetic engineering . . . is a science fiction expression suggesting the triumph of the phallogocentric lust to recreate the world without the intermediary of fleshy women's bodies." In genetic engineering, the assumption has been that DNA is the "master molecule," and introductory biology texts still call DNA by that name.[6] This isn't surprising given the hierarchical "central dogma" of DNA→ RNA→ Protein and the views of J.D. Watson ("the best home for a feminist is in another person's lab"). David Nanney (1957, 136) and Evelyn Fox Keller (1985, 150) have criticized this view, and Nanney has put forth an alternative model. He argues against the "Master Molecule concept. . . . This is in essence the theory of the Gene, interpreted to suggest a totalitarian government." He opposed this to "The 'Steady State' concept. By this term . . .we envision a dynamic self-perpetuating organization of a variety of molecular species which owes its specific properties not to the characteristic of any particular molecule, but to the functional interrelationships of these molecular species." E.E. Just, in fact, had criticized

McClung's notion of chromosomal hegemony on the same grounds. McClung (1924, 634) had claimed that, "Taken together, the chromosomes represent the sum total of all the elements of control over the processes of metabolism, irritability, contractibility, reproduction, etc., that are involved in the life of the organism." Note the use of the nucleus as the repository of all the *control* functions of the cell. Just (1936, 305) replied that "Such statements are absolutely without foundation in fact." Just (1936, 292) also linked nuclear hegemony with authoritarianism. It is not surprising that Nanney is one of the leading authorities on extrachromosomal inheritance and the cell cortex, and that E.E. Just attempted to popularize E.B. Wilson's observations on the eggs' activity in fertilization.

The master-molecule has become, in DNA, the unmoved mover of the changing cytoplasm. In this cellular version of the Aristotelian cosmos, the nucleus is the efficient cause (as Aristotle posited the sperm to be) while the cytoplasm (like Aristotle's conception of the female substrate) is merely the *material* cause. The nuclear DNA is the essence of domination and control. Macromolecule as machomolecule. Keller (1985) notes that on the cellular level, the hierarchical depiction of DNA in most textbooks looks like "organizational charts of corporate structures" and that genetic stability is ensured by the unidirectionality of information flow, much as political and social stability is assumed in many quarters to require the unidirectional exercise of authority." This hierarchy on the cellular level is supported by sociobiology on the organismal level. Here, bodies are merely vehicles for the propagation of genes. They are the fruit which nourishes the seeds. Similarly, the metaphors of sociobiology are drawn from the investment economics of our present society (Haraway 1979; Schwartz 1986).

The steady-state view of the cell is presently a minority opinion, but it has recently been eloquently expressed by Lynn Margulis and by Lewis Thomas (1974, 1). Here, the cell is seen as an ecologically interacting entity where process and interrelatedness are fundamental characteristics of life, not the properties of a single molecule.

The modeling of the nucleus began with a template of domination: "What controls what?" This was secondarily sexualized such that the nucleus (male) was seen as dominating the passive (female) cytoplasm. This sexualization of the cell has had enormously important affects on how biologists view the cell and this view, now "objectified" by science, supports the social behaviors which imposed it in the first place. The sexualization of the cell has placed blinders on researchers, making certain observations (and interpretations) "normal" and others "aberrant." In this section, we have tried to show that the tendency to equate activity with masculinity and passivity with femaleness has caused the research programs of fertilization and sex determination to be directed in a way different than it might have otherwise been. But can such degenderization succeed, or are we engrained in our telling of sexual

stories? There is a case where the degenderizing of the cell has succeeded to the benefit of the science. In protozoology at the turn of the century, gender distinctions had been placed on unicellular organisms (a strange situation considering these are cells and lack vaginas, penises, ovaries or testes). M. Hartmann (1929), one of the leading protozoologists of his time held that whenever differences were found within species, these differences would be male and female. In an article opposing this view, T.M. Sonneborn (1941, 705) noted that "the characteristics by which the female is ordinarily recognized are larger size, lesser activity, greater storage of nutritive reserves, and egg-like form; and the male by the corresponding opposite characters." Sonneborn pointed out that this dichotomy had created artificial problems that had directed research into less productive areas, and that a better protozoology could emerge if the male and female distinctions were abandoned. Sonneborn's ideas prevailed, and the analysis of mating types (*plus* and *minus*: "a" and "alpha"; not male and female) has become one of the most exciting areas of the field.

Fertilization Metaphors in Organic Chemistry

The sperm-egg interaction is a metaphor in-and-of-itself. Sometimes, the metaphor is explicit and sometimes implicit, but many things appear to interact "like the sperm and egg." Implied in this analogy is an active partner and a passive partner. We see this in many introductory textbooks of organic chemistry. Collisions between two molecules which lead to the formation of new compounds are often depicted sexually or aggressively, an active, small molecule "attacking" a large, passive, heavy compound. Nucleophilic and electrophilic "attacks" are standard language in organic chemistry. "The entering group is a negative species which is attacking the nucleus of the reactive carbon . . ." (Cason 1966, 66, 76). In the same book, college sophomores are also taught that "the nucleophile attempting a backside attack on the molecule is confronted with a problem that may be likened to the effort to penetrate a set of propellers spinning at high speed."

The notions of penetration and entry are often standard parts of organic chemistry lectures. It is not surprising to read that the "characteristic reaction of a carbene is insertion." Another book (Cook and Crump 1969, 71) describes the alkene bond as "being 'ripe for plucking' by an approaching electrophile." The heroic nucleophile or electrophile must be, like the sperm, tested. "The potency of a nucleophile in affecting a displacement is termed its nucleophilicity or nucleophilic strength" (Cason 1966, 363).

Who would have expected nucleophallic and electrophallic molecules? It appears that an arbitrary genderization of molecules has been made, where one of the colliding molecules is called the "attacking" group and the other is the passive recipient of this attack. In both nucleophilic and electrophilic

"attack," the "attacking" molecule is not the larger, but the smaller, faster one. The large molecules, those that are "looser" in terms of their electronic configuration (more resonance, pi-bonding) are the passive attacked groups. This arbitrary imagery is, we believe, analogous to small, hard mobile sperm penetrating the large, soft, immobile eggs. The imagery conforms to stereotypic attributions of maleness to energetic elements and femaleness to the passive ones. These stereotypes are being propagated by the language of science which gives students a wrong idea of nature (i.e., that it is gender-biased) but which purports to be objective.

NATURE AS TEXT

> "Like other sciences, biology today has lost many of its illusions. It is no longer seeking the truth. It is building its own truth."
> —Francois Jacob (1976,16)

Science is a creative human endeavor whereby individuals and groups of individuals collect data about the natural world and try to make sense of them. Each of the basic elements of scientific research—conceptualization, execution and interpretation—involves creativity. In fact, these three elements are the same as most any artistic, literary or musical endeavor. Two aspects of science are especially creative, namely the conceptual designing of an experiment and the interpreting of the results. Usually, the interpretation is put in the context of a narrative which includes the data but is not dependent upon them (Medawar 1963, 377; Figlio 1976, 17; Landau 1984, 262). Since science is a creative endeavor, it should be able to be criticized as such; and Lewis Thomas (1984, 155) has even suggested that schools of science criticism should exist parallel to that of literary, music and art criticism.

As a creative part of our social structure, biology should be amenable to analysis by feminist critique which has provided new insights into literature, art and the social sciences. Indeed, feminist examinations of sociobiology (Sayers 1982; Bleier 1984) primate research (Haraway 1986), and scientific methods (Keller 1985) have provided an important contribution to the literature of those fields. Researchers in those fields are aware of the feminist criticism and the result has created a better science—one in which methods of data collection and interpretation have been scrutinized for sexual biases.

Any creative enterprise undertaken by human beings is subject to the influences of society. It is not surprising, then, to see how gender becomes affixed to cells, nuclei and even chemicals. Even the interpretations of mathematical equations change with time! The interpretation that Newton gave to his Law of Gravity (i.e., that it was evidence of God's power and benevolence) differs (Dobbs 1985) from the interpretation of eighteenth century physicists (that it was evidence for a mechanical universe devoid of

purpose), and from that of contemporary physicists (that it is the consequence of gravitons traversing the curvature of space around matter).

By using feminist critique to analyze some of the history of biological thought, we are able to recognize areas where gender bias has informed how we think as biologists. In controlling for this bias, we can make biology a better discipline. Moreover, it is important that biology be kept strong and as free from gender bias as possible; for it is in a unique position to do harm or good. As Heschel has remarked (albeit with masculine pronouns):

> The truth of a theory about man is either creative or irrelevant, but never merely descriptive. A theory about the stars never becomes a part of the being of the stars. A theory about man enters his consciousness, determines his self-understanding, and modifies his very existence. The image of a man affects the nature of man . . . We become what we think of ourselves. (1965, 7)

A theory about life affects life. We become what biology tells us is the truth about life. Therefore, feminist critique of biology is not only good for biology but for our society as well. Biology needs it both for itself and for fulfilling its social responsibilities.

NOTES

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Lest anyone believe that this is strictly an academic exercise, the *New York Times* (25 March 1987, Sec. I, p. 20) recently reported an article wherein Adrianus Cardinal Simonis, Primate of the Netherlands, cited fertilization as evidence for the passive duties of women. In this essay, the Archbishop pointed to the egg that merely "waits" for the male's sperm, which he described as the "dynamic, active, masculine vector of new life."

1. The apparent exception of mammalian males was considered due to the extra burden *they* had when their mates were pregnant.

2. Once given "objectivity" by science, the notion that men are active because of their spermatic metabolism and women are passive because of their ovum-like ways finds its way into popular definition of masculinity and femininity. Freud (1933, 175) felt it necessary to counter this view when he lectured on "Femininity": "The male sex-cell is actively mobile and searches out the female one, and the latter, the ovum, is immobile and waits passively . . . The male pursues the female for the purpose of sexual union, seizes hold of her and penetrates into her. But by this you have precisely reduced the characteristsic of masculinity to the factor of aggressiveness as far as psychology is concerned." Freud recognized that "it is inadequate to make masculine behavior coincide with activity and feminine with passivity," and that "it serves no useful purpose and adds nothing to your knowledge."

3. There is ample evidence for the ovum as mythic princess. The ovum is not allowed to see sperm before it is of age, and when it travels to meet the sperm this "ripe" ovum not only has a "corona" (crown) but "vestments." It is also often said to have "attendant cells." According to Jung (1967, 171, 204), the hero is the symbol *par excellence* of the male libido and of the longing to reunite with the mother. If true, the sperm is an excellent embodiment of the heroic fantasy.

But this does not mean we have to follow this myth. Indeed, one could make a heroic tale about the ovum which has to take a "leap" into the unknown, though its chances of survival are less than 1%. Indeed, the human ovum, too, is a survivor of a process which has winnowed out nearly all of the original 2 million oocytes, and left it the only survivor of its cohort.

4. The "burrowing" metaphor is also commonly seen in textbooks, and it brings with it the seed-and-soil imagery. This plowing trope was, for many ancient cultures, a metaphor of necessary violence. The active/passive dichotomy is remarkably evident in the verb *to fertilize*. The traditional statement is that the "sperm fertilizes the egg." The sperm is active, the egg is passive. This inverts the original meaning of *fertilize* which involves the nourishment of seeds *by* the soil. The verb no longer connotes nutrition in this context, but activation.

5. Although Eicher and Washburn have emphasized that both sexes are actively created, at least two reviews on sex determination have recently proposed one or the other sex as being the "default" condition of the species. It should be noted that the views expressed in this essay may or may not be those of the scientists whose work we have reviewed. It is our contention that these research programs are inherently critical of a masculinist assumption with these respective fields. This does not mean that the research was consciously done with this in mind.

6. Metaphor and connotive language is extremely important in producing the gender-related images. Introductory biology textbooks also refer to the pituitary as "the master gland." (After all, it controls the other organs of sex and internal secretion from its privileged position in the brain. The apical, brainy organ controls the organs of lower functions; the sex glands being furthest removed.) There are other metaphors that could have been utilized. The pituitary could be called the "switchboard" gland (a female gender image) or the "integrator" gland (a dialectical image). Similarly, it is not merely a figure of speech to say that the seed analogy is at the heart of cell biology. The German word *Kern* (and Germany was where most of the pioneering work on cytology and fertilization was done) means more than the English equivalent "nucleus." It also means kernel, center, quintessence and elite position. Similarly both sperm and semen (and their German equivalents) have the same etymology, namely "seed." *Mater*, however, gives the root for maternal, material, matter and matrix.

The seed metaphor was so real to Leeuwenhoek that he actually performed dissections of plant seeds, insisting that the embryonic human would be found in the sperm just as the embryonic plants were found in the seeds (Ruestow 1983, 204). His "spermatozoa" were precisely that: mobile, ensouled, seed-animals. To him, the uterus (and the female sex) served to nourish the seed. The father was the sole parent.

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