Advances in Behavioral Biology (New York: Plenum Press), 333–65; G. Pugh (1977), *Biological Origins of Human Values* (New York: Basic Books); Crook (1972); and B. Campbell (1967), *Human Evolution: An Introduction to Man's Adaptations* (Chicago: Aldine).

13. Hite, S. (1976), *The Hite Report* (New York: Macmillan); Kinsey, A. *et al.* op. cit.
14. See, e.g. Davenport, W. (1977), 'Sex in Cross-Cultural Perspective', in F. Beach (ed.), *Human Sexuality in Four Perspectives* (Johns Hopkins University Press), 115–63.
15. Hite, S., op. cit.
16. Typically, in evolutionary explanations, if a trait is taken to have evolved as an adaptation, yet is rarely used in the adaptive context, some explanation of the details of the selection pressure or the extreme adaptive value of the trait is offered.
17. Morris, D. (1967), *The Naked Ape* (London: Jonathan Cape), 79.
18. Ibid. 55.
19. Ibid. 59.
20. Masters, W. H. and V. Johnson (1966), *Human Sexual Response* (Boston: Little, Brown).
21. Personal communication.
22. Gallup, G. and S. Suarez (1983), 'Optimal Reproductive Strategies for Bipedalism', *Journal of Human Evolution*, 12: 195.
23. This argument is spelled out in more detail by Stephen Jay Gould, in an essay that was based on my research and arguments ('Freudian Slip', *Natural History* (Feb. 1987), 14-21).
24. Kinsey, 1953; Hite (1976), 410–11.

7

The Egg and the Sperm: How Science has Constructed a Romance Based on Stereotypical Male–Female Roles

Emily Martin

> The theory of the human body is always a part of a world-picture. . . . The theory of the human body is always a part of a *fantasy*.[1]

As an anthropologist, I am intrigued by the possibility that culture shapes how biological scientists describe what they discover about the natural world. If this were so, we would be learning about more than the natural world in high school biology class; we would be learning about cultural beliefs and practices as if they were part of nature. In the course of my research I realized that the picture of egg and sperm drawn in popular as well as scientific accounts of reproductive biology relies on stereotypes central to our cultural definitions of male and female. The stereotypes imply not only that female biological processes are less worthy than their male counterparts but also that women are less worthy than men. Part of my goal in writing this article is to shine a bright light on the gender stereotypes hidden within the scientific language of biology. Exposed in such a light, I hope they will lose much of their power to harm us.

EGG AND SPERM: A SCIENTIFIC FAIRY TALE

At a fundamental level, all major scientific textbooks depict male and female reproductive organs as systems for the production of valuable substances, such as eggs and sperm.[2] In the case of women, the monthly cycle is described as being designed to produce eggs and prepare a suitable place for them to be fertilized and grown—

Reprinted from *Signs: Journal of Women in Culture and Society*, 16/3 (1991). By permission of the University of Chicago Press.

all to the end of making babies. But the enthusiasm ends there. By extolling the female cycle as a productive enterprise, menstruation must necessarily be viewed as a failure. Medical texts describe menstruation as the 'debris' of the uterine lining, the result of necrosis, or death of tissue. The descriptions imply that a system has gone awry, making products of no use, not to specification, unsaleable, wasted, scrap. An illustration in a widely used medical text shows menstruation as a chaotic disintegration of form, complementing the many texts that describe it as 'ceasing', 'dying', 'losing', 'denuding', 'expelling'.[3]

Male reproductive physiology is evaluated quite differently. One of the texts that sees menstruation as failed production employs a sort of breathless prose when it describes the maturation of sperm: 'The mechanisms which guide the remarkable cellular transformation from spermatid to mature sperm remain uncertain. . . . Perhaps the most amazing characteristic of spermatogenesis is its sheer magnitude: the normal human male may manufacture several hundred million sperm per day.'[4] In the classic text *Medical Physiology*, edited by Vernon Mountcastle, the male–female, productive–destructive comparison is more explicit: 'Whereas the female *sheds* only a single gamete each month, the seminiferous tubules *produce* hundreds of millions of sperm each day' (emphasis mine).[5] The female author of another text marvels at the length of the microscopic seminiferous tubules, which, if uncoiled and placed end to end, 'would span almost one-third of a mile!' She writes, 'In an adult male these structures produce millions of sperm cells each day.' Later she asks, 'How is this feat accomplished?'[6] None of these texts expresses such intense enthusiasm for any female processes. It is surely no accident that the 'remarkable' process of making sperm involves precisely what, in the medical view, menstruation does not: production of something deemed valuable.[7]

One could argue that menstruation and spermatogenesis are not analogous processes and, therefore, should not be expected to elicit the same kind of response. The proper female analogy to spermatogenesis, biologically, is ovulation. Yet ovulation does not merit enthusiasm in these texts either. Textbook descriptions stress that all of the ovarian follicles containing ova are already present at birth. Far from being *produced*, as sperm are, they merely sit on the shelf, slowly degenerating and aging like overstocked inventory: 'At birth, normal human ovaries contain an estimated one million follicles [each], and no new ones appear after birth. Thus, in marked

contrast to the male, the newborn female already has all the germ cells she will ever have. Only a few, perhaps 400, are destined to reach full maturity during her active productive life. All the others degenerate at some point in their development so that few, if any, remain by the time she reaches menopause at approximately 50 years of age.'[8] Note the 'marked contrast' that this description sets up between male and female: the male, who continuously produces fresh germ cells, and the female, who has stockpiled germ cells by birth and is faced with their degeneration.

Nor are the female organs spared such vivid descriptions. One scientist writes in a newspaper article that a woman's ovaries become old and worn out from ripening eggs every month, even though the woman herself is still relatively young: 'When you look through a laparoscope . . . at an ovary that has been through hundreds of cycles, even in a superbly healthy American female, you see a scarred, battered organ.'[9]

To avoid the negative connotations that some people associate with the female reproductive system, scientists could begin to describe male and female processes as homologous. They might credit females with 'producing' mature ova one at a time, as they're needed each month, and describe males as having to face problems of degenerating germ cells. This degeneration would occur throughout life among spermatogonia, the undifferentiated germ cells in the testes that are the long-lived, dormant precursors of sperm.

. . .

The real mystery is why the male's vast production of sperm is not seen as wasteful.[10] Assuming that a man 'produces' 100 million (10^8) sperm per day (a conservative estimate) during an average reproductive life of sixty years, he would produce well over two trillion sperm in his lifetime. Assuming that a woman 'ripens' one egg per lunar month, or thirteen per year, over the course of her forty-year reproductive life, she would total five hundred eggs in her lifetime. But the word 'waste' implies an excess, too much produced. Assuming two or three offspring, for every baby a woman produces, she wastes only around two hundred eggs. For every baby a man produces, he wastes more than one trillion (10^{12}) sperm.

How is it that positive images are denied to the bodies of women? A look at language—in this case, scientific language—provides the first clue. Take the egg and the sperm. It is remarkable how 'femininely' the egg behaves and how 'masculinely' the sperm.[11] The

egg is seen as large and passive.[12] It does not *move* or *journey*, but passively 'is transported', 'is swept',[13] or even 'drifts'[14] along the fallopian tube. In utter contrast, sperm are small, 'streamlined',[15] and invariably active. They 'deliver' their genes to the egg, 'activate the developmental program of the egg',[16] and have a 'velocity' that is often remarked upon.[17] Their tails are 'strong' and efficiently powered.[18] Together with the forces of ejaculation, they can 'propel the semen into the deepest recesses of the vagina'.[19] For this they need 'energy',[20] 'fuel',[20] so that with a 'whiplashlike motion and strong lurches'[21] they can 'burrow through the egg coat'[22] and 'penetrate' it.[23]

At its extreme, the age-old relationship of the egg and the sperm takes on a royal or religious patina. The egg coat, its protective barrier, is sometimes called its 'vestments', a term usually reserved for sacred, religious dress. The egg is said to have a 'corona',[24] a crown, and to be accompanied by 'attendant cells'.[25] It is holy, set apart and above, the queen to the sperm's king. The egg is also passive, which means it must depend on sperm for rescue. Gerald Schatten and Helen Schatten liken the egg's role to that of Sleeping Beauty: 'a dormant bride awaiting her mate's magic kiss, which instills the spirit that brings her to life'.[26] Sperm, by contrast, have a 'mission',[27] which is to 'move through the female genital tract in quest of the ovum'.[28] One popular account has it that the sperm carry out a 'perilous journey' into the 'warm darkness', where some fall away 'exhausted'. 'Survivors' 'assault' the egg, the successful candidates 'surrounding the prize'.[29] Part of the urgency of this journey, in more scientific terms, is that 'once released from the supportive environment of the ovary, an egg will die within hours unless rescued by a sperm'.[30] The wording stresses the fragility and dependency of the egg, even though the same text acknowledges elsewhere that sperm also live for only a few hours.[31]

In 1948, in a book remarkable for its early insights into these matters, Ruth Herschberger argued that female reproductive organs are seen as biologically interdependent, while male organs are viewed as autonomous, operating independently and in isolation:

. . .

> The sperm is no more independent of its milieu than the egg, and yet from a wish that it were, biologists have lent their support to the notion that the human female, beginning with the egg, is congenitally more dependent than the male.[32]

An article in the journal *Cell* has the sperm making an 'existential decision' to penetrate the egg: 'Sperm are cells with a limited behavioral repertoire, one that is directed toward fertilizing eggs. To execute the decision to abandon the haploid state, sperm swim to an egg and there acquire the ability to effect membrane fusion.[33] Is this a corporate manager's version of the sperm's activities—'executing decisions' while fraught with dismay over difficult options that bring with them very high risk.

. . .

One depiction of sperm as weak and timid, instead of strong and powerful—the only such representation in Western civilization, so far as I know—occurs in Woody Allen's movie *Everything You Always Wanted To Know About Sex* *But Were Afraid to Ask.* Allen, playing the part of an apprehensive sperm inside a man's testicles, is scared of the man's approaching orgasm. He is reluctant to launch himself into the darkness, afraid of contraceptive devices, afraid of winding up on the ceiling if the man masturbates.

The more common picture—egg as damsel in distress, shielded only by her sacred garments; sperm as heroic warrior to the rescue—cannot be proved to be dictated by the biology of these events. While the 'facts' of biology may not *always* be constructed in cultural terms, I would argue that in this case they are. The degree of metaphorical content in these descriptions, the extent to which differences between egg and sperm are emphasized, and the parallels between cultural stereotypes of male and female behaviour and the character of egg and sperm all point to this conclusion.

NEW RESEARCH, OLD IMAGERY

As new understandings of egg and sperm emerge, textbook gender imagery is being revised. But the new research, far from escaping the stereotypical representations of egg and sperm, simply replicates elements of textbook gender imagery in a different form. The persistence of this imagery calls to mind what Ludwik Fleck termed 'the self-contained' nature of scientific thought. As he described it, 'the interaction between what is already known, what remains to be learned, and those who are to apprehend it, go to ensure harmony within the system. But at the same time they also preserve the harmony of illusions, which is quite secure within the confines of a given thought style.[34] We need to understand the way in which the

cultural content in scientific descriptions changes as biological discoveries unfold, and whether that cultural content is solidly entrenched or easily changed.

In all of the texts quoted above, sperm are described as penetrating the egg, and specific substances on a sperm's head are described as binding to the egg. Recently, this description of events was rewritten in a biophysics lab at Johns Hopkins University—transforming the egg from the passive to the active party.[35]

Prior to this research, it was thought that the zona, the inner vestments of the egg, formed an impenetrable barrier. Sperm overcame the barrier by mechanically burrowing through, thrashing their tails and slowly working their way along. Later research showed that the sperm released digestive enzymes that chemically broke down the zona; thus, scientists presumed that the sperm used mechanical *and* chemical means to get through to the egg.

In this recent investigation, the researchers began to ask questions about the mechanical force of the sperm's tail. (The lab's goal was to develop a contraceptive that worked topically on sperm.) They discovered, to their great surprise, that the forward thrust of sperm is extremely weak, which contradicts the assumption that sperm are forceful penetrators.[36] Rather than thrusting forward, the sperm's head was now seen to move mostly back and forth. The sideways motion of the sperm's tail makes the head move sideways with a force that is ten times stronger than its forward movement. So even if the overall force of the sperm were strong enough to mechanically break the zona, most of its force would be directed sideways rather than forward. In fact, its strongest tendency, by tenfold, is to escape by attempting to pry itself off the egg. Sperm, then, must be exceptionally efficient at *escaping* from any cell surface they contact. And the surface of the egg must be designed to trap the sperm and prevent their escape. Otherwise, few if any sperm would reach the egg.

The researchers at Johns Hopkins concluded that the sperm and egg stick together because of adhesive molecules on the surfaces of each. The egg traps the sperm and adheres to it so tightly that the sperm's head is forced to lie flat against the surface of the zona, a little bit, they told me, 'like Br'er Rabbit getting more and more stuck to tar baby the more he wriggles'. The trapped sperm continues to wiggle ineffectually side to side. The mechanical force of its tail is so weak that a sperm cannot break even one chemical bond. This is where the digestive enzymes released by the sperm come in. If they start to soften the zona just at the tip of the sperm and the sides

remain stuck, then the weak, flailing sperm can get oriented in the right direction and make it through the zona—provided that its bonds to the zona dissolve as it moves in.

Although this new version of the saga of the egg and the sperm broke through cultural expectations, the researchers who made the discovery continued to write papers and abstracts as if the sperm were the active party who attacks, binds, penetrates, and enters the egg. The only difference was that sperm were now seen as performing these actions weakly.[37] Not until August 1987, more than three years after the findings described above, did these researchers reconceptualize the process to give the egg a more active role. They began to describe the zona as an aggressive sperm catcher, covered with adhesive molecules that can capture a sperm with a single bond and clasp it to the zona's surface.[38] In the words of their published account: 'The innermost vestment, the *zona pellucida*, is a glyco-protein shell, which captures and tethers the sperm before they penetrate it. . . . The sperm is captured at the initial contact between the sperm tip and the *zona*. . . . Since the thrust [of the sperm] is much smaller than the force needed to break a single affinity bond, the first bond made upon the tip-first meeting of the sperm and *zona* can result in the capture of the sperm.[39]

Experiments in another lab reveal similar patterns of data interpretation. Gerald Schatten and Helen Schatten set out to show that, contrary to conventional wisdom, the 'egg is not merely a large, yolk-filled sphere into which the sperm burrows to endow new life. Rather, recent research suggests the almost heretical view that sperm and egg are mutually active partners'.[40] This sounds like a departure from the stereotypical textbook view, but further reading reveals Schatten and Schatten's conformity to the aggressive-sperm metaphor. They describe how 'the sperm and egg first touch when, from the tip of the sperm's triangular head, a long, thin filament shoots out and harpoons the egg'. Then we learn that 'remarkably, the harpoon is not so much fired as assembled at great speed, molecule by molecule, from a pool of protein stored in a specialized region called the acrosome. The filament may grow as much as twenty times longer than the sperm head itself before its tip reaches the egg and sticks.'[41] why not call this 'making a bridge' or 'throwing out a line' rather than firing a harpoon? Harpoons pierce prey and injure or kill them, while this filament only sticks. And why not focus, as the Hopkins lab did, on the stickiness of the egg, rather than the stickiness of the sperm? Later in the article, the Schattens

replicate the common view of the sperm's perilous journey into the warm darkness of the vagina, this time for the purpose of explaining its journey into the egg itself: '[The sperm] still has an arduous journey ahead. It must penetrate farther into the egg's huge sphere of cytoplasm and somehow locate the nucleus, so that the two cells' chromosomes can fuse. The sperm dives down into the cytoplasm, its tail beating. But it is soon interrupted by the sudden and swift migration of the egg nucleus, which rushes toward the sperm with a velocity triple that of the movement of chromosomes during cell division, crossing the entire egg in about a minute.[42]

Like Schatten and Schatten and the biophysicists at Johns Hopkins, another researcher has recently made discoveries that seem to point to a more interactive view of the relationship of egg and sperm. This work, which Paul Wassarman conducted on the sperm and eggs of mice, focuses on identifying the specific molecules in the egg coat (the zona pellucida) that are involved in egg–sperm interaction. At first glance, his descriptions seem to fit the model of an egalitarian relationship. Male and female gametes 'recognize one another', and 'interactions . . . take place between sperm and egg'.[43] But the article in *Scientific American* in which those descriptions appear begins with a vignette that presages the dominant motif of their presentation: 'It has been more than a century since Hermann Fol, a Swiss zoologist, peered into his microscope and became the first person to see a sperm penetrate an egg, fertilize it and form the first cell of a new embryo'.[44] This portrayal of the sperm as the active party—the one that *penetrates* and *fertilizes* the egg and *produces* the embryo—is not cited as an example of an earlier, now outmoded view. In fact, the author reiterates the point later in the article: 'Many sperm can bind to and penetrate the zona pellucida, or outer coat, of an unfertilized mouse egg, but only one sperm will eventually fuse with the thin plasma membrane surrounding the egg proper (*inner sphere*), fertilizing the egg and giving rise to a new embryo'.[45]

The imagery of sperm as aggressor is particularly startling in this case: the main discovery being reported is isolation of a particular molecule *on the egg coat* that plays an important role in fertilization! Wassarman's choice of language sustains the picture. He calls the molecule that has been isolated, ZP3, a 'sperm receptor'. By allocating the passive, waiting role to the egg, Wassarman can continue to describe the sperm as the actor, the one that makes it all happen: 'The basic process begins when many sperm first attach loosely and then bind tenaciously to receptors on the surface of the egg's thick outer coat, the zona pellucida. Each sperm, which has a large number of egg-binding proteins on its surface, binds to many sperm receptors on the egg. More specifically, a site on each of the egg-binding proteins fits a complementary site on a sperm receptor, much as a key fits a lock.'[46] With the sperm designated as the 'key' and the egg the 'lock', it is obvious which one acts and which one is acted upon. Could this imagery not be reversed, letting the sperm (the lock) wait until the egg produces the key? Or could we speak of two halves of a locket matching, and regard the matching itself as the action that initiates the fertilization?

It is as if Wassarman were determined to make the egg the receiving partner. Usually in biological research, the *protein* member of the pair of binding molecules is called the receptor, and physically it has a pocket in it rather like a lock. As the diagrams that illustrate Wassarman's article show, the molecules on the sperm are proteins and have 'pockets'. The small, mobile molecules that fit into these pockets are called ligands. As shown in the diagrams, ZP3 on the egg is a polymer of 'keys'; many small knobs stick out. Typically, molecules on the sperm would be called receptors and molecules on the egg would be called ligands. But Wassarman chose to name ZP3 on the egg the receptor and to create a new term, 'the egg-binding protein', for the molecule on the sperm that otherwise would have been called the receptor.[47]

. . .

SOCIAL IMPLICATIONS: THINKING BEYOND

All three of these revisionist accounts of egg and sperm cannot seem to escape the hierarchical imagery of older accounts. Even though each new account gives the egg a larger and more active role, taken together they bring into play another cultural stereotype: woman as a dangerous and aggressive threat. In the Johns Hopkins lab's revised model, the egg ends up as the female aggressor who 'captures and tethers' the sperm with her sticky zona, rather like a spider lying in wait in her web.[48] The Schatten lab has the egg's nucleus 'interrupt' the sperm's dive with a 'sudden and swift' rush by which she 'clasps the sperm and guides its nucleus to the center'.[49] Wassarman's description of the surface of the egg 'covered with thousands of plasma membrane-bound projections, called

microvilli' that reach out and clasp the sperm adds to the spiderlike imagery.[50]

These images grant the egg an active role but at the cost of appearing disturbingly aggressive. Images of woman as dangerous and aggressive, the *femme fatale* who victimizes men, are widespread in Western literature and culture.[51] More specific is the connection of spider imagery with the idea of an engulfing, devouring mother.[52] New data did not lead scientists to eliminate gender stereotypes in their descriptions of egg and sperm. Instead, scientists simply began to describe egg and sperm in different, but no less damaging, terms.

Can we envision a less stereotypical view? Biology itself provides another model that could be applied to the egg and the sperm. The cybernetic model—with its feedback loops, flexible adaptation to change, co-ordination of the parts within a whole, evolution over time, and changing response to the environment—is common in genetics, endocrinology, and ecology and has a growing influence in medicine in general.[53] This model has the potential to shift our imagery from the negative, in which the female reproductive system is castigated both for not producing eggs after birth and for producing (and thus wasting) too many eggs overall, to something more positive. The female reproductive system could be seen as responding to the environment (pregnancy or menopause), adjusting to monthly changes (menstruation), and flexibly changing from reproductivity after puberty to non-reproductivity later in life. The sperm and egg's interaction could also be described in cybernetic terms. J. F. Hartman's research in reproductive biology demonstrated fifteen years ago that if an egg is killed by being pricked with a needle, live sperm cannot get through the zona.[54] Clearly, this evidence shows that the egg and sperm *do* interact on more mutual terms, making biology's refusal to portray them that way all the more disturbing.

We would do well to be aware, however, that cybernetic imagery is hardly neutral. In the past, cybernetic models have played an important part in the imposition of social control. These models inherently provide a way of thinking about a 'field' of interacting components. Once the field can be seen, it can become the object of new forms of knowledge, which in turn can allow new forms of social control to be exerted over the components of the field. During the 1950s, for example, medicine began to recognize the psychosocial *environment* of the patient: the patient's family and its psychodynamics. Professions such as social work began to focus on

this new environment, and the resulting knowledge became one way to further control the patient. Patients began to be seen not as isolated, individual bodies, but as psychosocial entities located in an 'ecological' system: management of 'the patient's psychology was a new entrée to patient control'.[55]

The models that biologists use to describe their data can have important social effects. During the nineteenth century, the social and natural sciences strongly influenced each other: the social ideas of Malthus about how to avoid the natural increase of the poor inspired Darwin's *Origin of Species*.[56] Once the *Origin* stood as a description of the natural world, complete with competition and market struggles, it could be reimported into social science as social Darwinism, in order to justify the social order of the time. What we are seeing now is similar: the importation of cultural ideas about passive females and heroic males into the 'personalities' of gametes. This amounts to the 'implanting of social imagery on representations of nature so as to lay a firm basis for reimporting exactly that same imagery as natural explanations of social phenomena'.[57]

Further research would show us exactly what social effects are being wrought from the biological imagery of egg and sperm. At the very least, the imagery keeps alive some of the hoariest old stereotypes about weak damsels in distress and their strong male rescuers. That these stereotypes are now being written in at the level of the *cell* constitutes a powerful move to make them seem so natural as to be beyond alteration.

The stereotypical imagery might also encourage people to imagine that what results from the interaction of egg and sperm—a fertilized egg—is the result of deliberate 'human' action at the cellular level. Whatever the intentions of the human couple, in this microscopic 'culture' a cellular 'bride' (or *femme fatale*) and a cellular 'groom' (her victim) make a cellular baby. Rosalind Petchesky points out that through visual representations such as sonograms, we are given '*images* of younger and younger, and tinier and tinier, fetuses being "saved" '. This leads to 'the point of visibility being "pushed back" *indefinitely*'.[58] Endowing egg and sperm with intentional action, a key aspect of personhood in our culture, lays the foundation for the point of viability being pushed back to the moment of fertilization. This will likely lead to greater acceptance of technological developments and new forms of scrutiny and manipulation, for the benefit of these inner 'persons': court-ordered restrictions on a pregnant woman's

activities in order to protect her fetus, fetal surgery, amniocentesis, and rescinding of abortion rights, to name but a few examples.[59]

Even if we succeed in substituting more egalitarian, interactive metaphors to describe the activities of egg and sperm, and manage to avoid the pitfalls of cybernetic models, we would still be guilty of endowing cellular entities with personhood. More crucial, then, than what *kinds* of personalities we bestow on cells is the very fact that we are doing it at all. This process could ultimately have the most disturbing social consequences.

One clear feminist challenge is to wake up sleeping metaphors in science, particularly those involved in descriptions of the egg and the sperm. Although the literary convention is to call such metaphors 'dead', they are not so much dead as sleeping, hidden within the scientific content of texts—and all the more powerful for it.[60] Waking up such metaphors, by becoming aware of when we are projecting cultural imagery onto what we study, will improve our ability to investigate and understand nature. Waking up such metaphors, by becoming aware of their implications, will rob them of their power to naturalize our social conventions about gender.

Notes

1. James Hillman, *The Myth of Analysis* (Evanston, Ill.: Northwestern University Press, 1972), 220.
2. The textbooks I consulted are the main ones used in classes for undergraduate premedical students or medical students (or those held on reserve in the library for these classes) during the past few years at Johns Hopkins University. These texts are widely used at other universities in the country as well.
3. Arthur C. Guyton, *Physiology of the Human Body*, 6th edn. (Philadelphia: Saunders College Publishing, 1984), 624.
4. Arthur J. Vander, James H. Sherman, and Dorothy S. Luciano, *Human Physiology: The Mechanisms of Body Function*, 3d edn. (New York: McGraw-Hill, 1980), 483–4.
5. Vernon B. Mountcastle, *Medical Physiology*, 14th edn. (London: Mosby, 1980), 2:1624.
6. Eldra Pearl Solomon, *Human Anatomy and Physiology* (New York: CBS College Publishing, 1983), 678.
7. For elaboration, see Emily Martin, *The Woman in the Body: A Cultural Analysis of Reproduction* (Boston: Beacon, 1987), 27–53.
8. Vander, Sherman, and Luciano, 568.
9. Melvin Konner, 'Childbearing and Age', *New York Times Magazine* (27 Dec. 1987), 22–3, esp. 22.
10. In her essay 'Have Only Men Evolved?' (in Sandra Harding and Merrill B. Hintikka (eds.), *Discovering Reality: Feminist Perspectives on Epistemology, Metaphysics, Methodology, and Philosophy of Science* (Dordrecht: Reidel, 1983), 45–69, esp. 60–1), Ruth Hubbard points out that sociobiologists have said the female invests more energy than the male in the production of her large gametes, claiming that this explains why the female provides parental care. Hubbard questions whether it 'really takes more "energy" to generate the one or relatively few eggs than the large excess of sperms required to achieve fertilization'.
11. See Carol Delaney, 'The Meaning of Paternity and the Virgin Birth Debate', *Man*, 21/3 (Sept. 1986), 494–513. She discusses the difference between this scientific view that women contribute genetic material to the fetus and the claim of long-standing Western folk theories that the origin and identity of the fetus comes from the male, as in the metaphor of planting a seed in soil.
12. For a suggested direct link between human behaviour and purportedly passive eggs and active sperm, see Erik H. Erikson, 'Inner and Outer Space: Reflections on Womanhood', *Daedalus*, 93/2 (Spring 1964), 582–606, esp. 591.
13. Guyton (n. 3 above), 619; and Mountcastle (n. 5 above), 1609.
14. Jonathan Miller and David Pelham, *The Facts of Life* (New York: Viking Penguin, 1984), 5.
15. Bruce Alberts *et al.*, *Molecular Biology of the Cell* (New York: Garland, 1983), 796.
16. Ibid. 796.
17. See, e.g. William F. Ganong, *Review of Medical Physiology*, 7th edn. (Los Altos, Calif.: Lange Medical Publications, 1975), 322.
18. Alberts *et al.* (n. 15 above), 796.
19. Guyton, 615.
20. Solomon (n. 6 above), 683.
21. Vander, Sherman, and Luciano (n. 4 above), 4th edn. (1985), 580.
22. Alberts *et al.*, 796.
23. All biology texts quoted above use the word 'penetrate'.
24. Solomon, 700.
25. A. Beldecos *et al.*, 'The Importance of Feminist Critique for Contemporary Cell Biology', *Hypatia*, 3/1 (Spring 1988), 61–76.
26. Gerald Schatten and Helen Schatten, 'The Energetic Egg', *Medical World News*, 23 (23 Jan. 1984), 51–3, esp. 51.
27. Alberts *et al.*, 796.
28. Guyton (n. 3 above), 613.
29. Miller and Pelham (n. 14 above), 7.
30. Alberts *et al.* (n. 15 above), 804.
31. Ibid. 801.
32. Ruth Herschberger, *Adam's Rib* (New York: Pelligrini & Cudaby, 1948), esp. 84.
33. Bennett M. Shapiro, 'The Existential Decision of a Sperm', *Cell*, 49/3 (May 1987), 293–4, esp. 293.
34. Ludwik Fleck, *Genesis and Development of a Scientific Fact*, ed. Thaddeus J. Trenn and Robert K. Merton (Chicago: University of Chicago Press, 1979), 38.
35. Jay M. Baltz carried out the research I describe when he was a graduate student in the Thomas C. Jenkins Department of Biophysics at Johns Hopkins University.
36. Far less is known about the physiology of sperm than comparable female

substances, which some feminists claim is no accident. Greater scientific scrutiny of female reproduction has long enabled the burden of birth control to be placed on women. In this case, the researchers' discovery did not depend on development of any new technology. The experiments made use of glass pipettes, a manometer, and a simple microscope, all of which have been available for more than one hundred years.

37. Jay Baltz and Richard A. Cone, 'What Force Is Needed to Tether a Sperm?' (abstract for Society for the Study of Reproduction, 1985), and 'Flagellar Torque on the Head Determines the Force Needed to Tether a Sperm' (abstract for Biophysical Society, 1986).
38. Jay M. Baltz, David F. Katz, and Richard A. Cone, 'The Mechanics of the Sperm–Egg Interaction at the Zona Pellucida', *Biophysical Journal*, 54/4 (Oct. 1988), 643–54.
39. Ibid. 643, 650.
40. Schatten and Schatten (n. 26 above), 51.
41. Ibid. 52.
42. Schatten and Schatten, 53.
43. Paul M. Wassarman, 'Fertilization in Mammals', *Scientific American*, 259/6 (Dec. 1988), 78–84, esp. 78, 84.
44. Ibid. 78.
45. Ibid. 79.
46. Ibid. 78.
47. Since receptor molecules are relatively *immotile* and the ligands that bind to them relatively *motile*, one might imagine the egg being called the receptor and the sperm the ligand. But the molecules in question on egg and sperm are immotile molecules. It is the sperm as a *cell* that has motility, and the egg as a cell that has relative immotility.
48. Baltz, Katz, and Cone (n. 38 above), 643, 650.
49. Schatten and Schatten, 53.
50. Paul M. Wassarman, 'The Biology and Chemistry of Fertilization', *Science*, 235/4788 (30 Jan. 1987), 553–60, esp. 554.
51. Mary Ellman, *Thinking about Women* (New York: Harcourt Brace Jovanovich, 1968), 140; Nina Auerbach, *Woman and the Demon* (Cambridge, Mass.: Harvard University Press, 1982), esp. 186.
52. Kenneth Alan Adams, 'Arachnophobia: Love American Style', *Journal of Psychoanalytic Anthropology*, 4/2 (1981), 157–97.
53. William Ray Arney and Bernard Bergen, *Medicine and the Management of Living* (Chicago: University of Chicago Press, 1984).
54. J. F. Hartman, R. B. Gwatkin, and C. F. Hutchison, 'Early Contact Interactions between Mammalian Gametes *In Vitro*', *Proceedings of the National Academy of Sciences (US)* 69/10 (1972), 2767–9.
55. Arney and Bergen, 68.
56. Ruth Hubbard, 'Have Only Men Evolved?' (n. 10 above), 51–2.
57. David Harvey, personal communication, Nov. 1989.
58. Rosalind Petchesky, 'Fetal Images: The Power of Visual Culture in the Politics of Reproduction', *Feminist Studies*, 13/2 (Summer 1987), 263–92, esp. 272.
59. Rita Arditti, Renate Klein, and Shelley Minden, *Test-Tube Women* (London: Pandora, 1984); Ellen Goodman, 'Whose Right to Life?' *Baltimore Sun* (17 Nov. 1987); Tamar Lewin, 'Courts Acting to Force Care of the Unborn', *New York Times* (23 Nov. 1987), A1 and B10; Susan Irwin and Brigitte Jordan, Knowledge, Practice, and Power: Court Ordered Cesarean Sections', *Medical Anthropology Quarterly*, 1/3 (Sept. 1987), 319–34.
60. Thanks to Elizabeth Fee and David Spain, who in February 1989 and April 1989, respectively, made points related to this.