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NATURE



DR TATIANA'S SEX ADVICE TO ALL CREATION



THE DEFINITIVE GUIDE TO THE
EVOLUTIONARY BIOLOGY OF SEX

OLIVIA JUDSON

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About the Book

If you have ever wondered why women always bite your head off or why one guy gets all the girls, if you have ever pondered why some men bring you balloons while others leave you their genitals, then *Dr Tatiana's Sex Advice to All Creation* is the book for you. It explains all this and much more. It discloses the best time to have a sex change, how to have a virgin birth, when to seduce your sisters or eat your lover. Quirky and brilliant, it takes as its starting point all creatures great and small worried about their bizarre sex lives, and the letters they write to the wise Dr Tatiana, the only agony aunt in all creation with a prodigious knowledge of both natural history and evolutionary biology.

About the Author

An alumna of Stanford with a doctorate in biological sciences from Oxford University, Olivia Judson is an evolutionary biologist and award-winning science journalist who has published in *Nature*, *Science*, the *Guardian* and *The Economist*. Winner of the prestigious Glaxo Wellcome/Association of British Science Writers' award, she is currently a research fellow at Imperial College, London. This is her first book.

Visit Dr. Tatiana at her website: www.drtatiana.com.

For Horace, who taught me to write

Olivia Judson

DR. TATIANA'S
SEX ADVICE
TO ALL
CREATION

The Definitive Guide
to the Evolutionary
Biology of Sex

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AGONY AND ECSTASY: A NOTE FROM DR. TATIANA

In my business I get asked a lot of questions. Many of them concern matters beyond the wildest human imaginings. But the most common question is mundane enough: Why did I become a sex expert? Quite simply, I decided to dedicate myself to sex when I realized that nothing in life is more important, more interesting—or more troublesome.

If not for sex, much of what is flamboyant and beautiful in nature would not exist. Plants would not bloom. Birds would not sing. Deer would not sprout antlers. Hearts would not beat so fast. But ask an assortment of creatures, what is sex? and they will give you different answers. Humans and many other species will say copulation. Frogs and most fish will say the squirting of eggs and sperm in joint shudders of spawning. Scorpions, millipedes, and salamanders will tell you that sex is packets of sperm deposited on the ground for the female to sit on so they'll explode into her reproductive tract. A sea urchin will say sex is releasing eggs and sperm into the sea in the hope that they will, somehow, find each other in the waves. For flowering plants, sex is trusting the wind or an insect to carry pollen to a receptive female flower.

To succeed, each of these methods requires a suite of different features. A male flower who wishes to be a Lothario and have his pollen strewn to as many mates as possible must seduce not female flowers but bees. Other creatures must wear gaudy costumes, be they fancy feathers or frivolous fins; they must sing and dance for hours and hours; they must perform prodigious feats,

building and rebuilding nests and bowers. In short, they must expend enormous energy shouting, “Choose *me*, choose *me*.” And all for—what?

In truth, these various practices are just the means to an end. The ultimate sex act—the act that all these antics have evolved to accomplish—is the mixing of genes, the creation of an individual with a new genetic makeup. To a miserable organism sitting alone in a singles bar, genetic mixing might not seem worth the bother. Yet it is fundamental to the grand scheme of things. To see why, let’s take a step back and think about how evolution works.

For most of us, caught up in the hurly-burly of our daily struggles, the purpose of life may seem elusive. But from an evolutionary point of view, the purposes of life are clear: survival and reproduction. If you fail at either, your genes go with you to the grave. If you succeed at both, you pass your genes on to your children. Inevitably—such is life—some organisms do better than others at surviving and reproducing. If everyone had identical genes, then differences in survival and reproduction would be due to luck, not genes. But usually individuals have different genes. And insofar as a particular gene confers an advantage in terms of survival or reproduction, that gene will spread.

This simple process, discovered by Charles Darwin and Alfred Russel Wallace in the nineteenth century, is the principal mechanism of evolution. It is known as natural selection. Sometimes the process is fast and easy to see. Suppose a poison—an antibiotic, say, or an insecticide—appears in the environment. And suppose that surviving the poison depends on having a particular gene. Those who do not have the gene will die, their genes “deselected” from the population. In the extreme case, no one has the resistance gene, everyone dies, and the population becomes extinct. More often than not, however, some individuals are fortunate and have a gene to resist the

poison. Since these individuals are the only ones to survive and reproduce, the genetic makeup of the population will shift to one where everybody is resistant.

Thus, genetic variation is crucial: no genetic variation, no evolution. But where does genetic variation come from? There are two main sources: mutation—and sex. Mutation, or random changes to information contained in genes, is the more primitive of the two. Mutations arise from errors made by the cell's genetic copying machinery. Since no scribe is perfect, some errors are inevitable—which is just as well. Whereas sex produces new combinations of genes that already exist, mutation creates altogether new genes—and thus generates the raw material of evolution. Without mutation, evolution would grind to a halt.

Yet mutation by itself is not enough. From time to time organisms evolve to give up sex, reproducing asexually instead. When this happens, any genetic differences between a parent and child are, by definition, due to mutation only. At first, asexual organisms often flourish. But their glory is fleeting. For reasons that remain mysterious, the loss of sex is almost always followed by swift extinction. Apparently, without sex you are doomed.

Which is not to say that sex makes life easy. No matter, how good your survival skills are—you can be the champion at evading predators, or have the best nose for finding food, or be immune to every disease—it will all be for naught if you cannot find, impress, and seduce a mate. Worse, success at seduction is often at odds with survival. If you're a bird, flaunting an enormous tail may make you quite the cock among hens—but it may also make you lunch for a cat. Worse still, the competition for mates is often exceedingly stiff.

The upshot of all this is that the need to find and seduce a mate is among the most powerful forces in evolution. Perhaps nothing in life generates a more ecstatic diversity of tactics and stratagems, a more surprising array of forms

and behaviors. In comparison, tricks to avoid predators seem predictable and limited. They typically include one or more of the following features: going about in groups, moving fast, blending in with your surroundings, looking scary, sporting a shell or sharp bits, or tasting revolting. But tricks to seduce a partner—ah, here the variety is endless. Which is why everyone asks so many questions.

And which is why I have dedicated my life to answering them. In the pages that follow, I have chosen samples of my correspondence over the years. I have deliberately selected questions that seem to me to address the concerns of all creatures, such as promiscuity, infidelity, and homosexuality. I have grouped questions on related topics into chapters, each of which has the briefest of introductions and concludes with a summary of my advice.

The chapters, in turn, fall into three related parts. In the first part, “Let Slip the Whores of War!” I reveal the reasons that males and females so often want different things from each other, and from life, and I explore some of the consequences. The second part, “The Evolution of Depravity,” discusses situations where the collision is at its most intense—sometimes generating horrific outcomes, including rape and cannibalism. This part finishes with a brief chapter on the rarest, most aberrant evolutionary phenomenon: monogamy.

The last section goes further still, to ask “Are Men Necessary?” Here, I consider various matters to do with the evolution of gender and of sex. In an attempt to find out why sex is so essential for long-term evolutionary success, the final chapter is a discussion with the only organism so far known to have succeeded in living for millions and millions of years without it.

What of my methods? To respond to my readers, I have sifted through the scientific literature, reading hundreds of books and papers; I have interviewed specialists on subjects from dwarf males to giant sperm. When the

answer is not known to science, as often it is not, I have given my best guess based on the knowledge available and my understanding of natural selection. Sometimes, as a result of my research, I have come to conclusions that are different from the prevailing wisdom; thus, I hope that in a small way this book makes a contribution to ongoing debates. In that spirit of open scientific inquiry I have provided, at the end of the book, all my sources.

I have found from experience that most organisms prefer to be called by their common names rather than by their technical Latin names—after all, few humans talk of themselves as *Homo sapiens*—so I use Latin names only when necessary for clarity or when the organism I am discussing is too obscure (or too snobbish) to have a common name. In observance of scientific custom, I have given measurements in metric units. However, in those instances where I felt it would be helpful to my readers in North America, I have provided conversions. Finally, I would like to thank my correspondents for agreeing to let me make public problems of a most intimate nature. This book would not have been possible without them.

PART I

**LET SLIP
THE WHORES OF WAR!**

The battle of the sexes is no myth. Success at sexual reproduction is at the heart of the evolutionary process. But greater success for her often means less success for him. The upshot? An eternal war—and an astounding diversity of strategies.

•1•

A SKETCH OF THE BATTLEFIELD

BOYS ARE PROMISCUOUS and girls are chaste, right? Wrong. The battle of the sexes erupts because, in most species, girls are wanton.

Dear Dr. Tatiana,

My name's Twiggy, and I'm a stick insect. It's with great embarrassment that I write to you while copulating, but my mate and I have been copulating for ten weeks already. I'm bored out of my skull, yet he shows no sign of flagging. He says it's because he's madly in love with me, but I think he's just plain mad. How can I get him to quit?

Sick of Sex in India

Who'd have thought a stick insect would be among the world's most tireless lovers? Ten weeks! I can see why you've had enough. Twiggy, your suspicions are half right. Your paramour *is* mad, though not with love but with jealousy. By continually copulating he can guarantee that no one else will have a chance to get near you. It's a good thing he's only half your length, so he's not too heavy to carry about.

Is your case unusual? Well, it is extreme, but by no means unique. Males in many species are fiercely possessive of their mates. Look at the Idaho ground squirrel, a rare critter that lives only in (surprise) Idaho. The male won't let his partner out of his sight and follows her everywhere. If she goes into a burrow he sits at the entrance so she can't come out—and no one else can go in. Worse, he picks fights

with any other male who happens to come near. Or consider the blue milkweed beetle. After sex—which by any insect standards is brief, taking only ten minutes or so—the male insists on riding around on the female’s back, not so he can whisper sweet nothings but so he can stop her from gallivanting.

To be frank, though, males have good reason to be possessive. Given half a chance, girls in most species will leap into bed with another fellow. “But wait,” I hear you cry, “isn’t it a general law of nature that males are promiscuous and females are chaste?” That is indeed what used to be thought. But now we know this notion is nonsense.

The man who first lent scientific respectability to this notion was named A. J. Bateman. In 1948, he published a paper in the scientific journal *Heredity* in which he claimed to have proved that males have evolved to make love and females to make babies. His assertions were based on experiments he had conducted with the fruit fly *Drosophila melanogaster*. This is one of those small flies drawn to bowls of ripening fruit or to glasses of wine, and should on no account be confused with the larger housefly, which likes feces and other muck. *Drosophila* boasts perhaps as many as two thousand different species, with more than four hundred in Hawaii alone. Little is known about most of them. But *Drosophila melanogaster* is beloved of geneticists and, along with the worm, the mouse, and the human, is one of the most studied animals on earth.

After keeping equal numbers of adult male and female flies together in small bottles for three or four days, Bateman noticed that the males were keen to mate as often as possible, ardently vibrating their wings for any girl who’d pay attention. If a female was receptive, the male would press his suit, licking her genitalia before gently spreading her wings and mounting her. Most of the time, however, the males were disappointed. Bateman observed that female flies tended to reject the advances of more than

one or two suitors. In accordance with this observation, he also found that while males had more children the more partners they mated with, females did not.

To explain his results, Bateman appealed to what he saw as the essential difference between the sexes—that males produce lots of tiny, cheap sperm whereas females produce a few large, expensive eggs. He also noted that the females of many species can store sperm for days, months, or in some cases years, which means that sperm from one mating can, in principle, last a lifetime. Therefore, Bateman argued, one male could easily fertilize all the eggs of many females. Accordingly, he went on, females are limited in their reproduction by how fast they can make eggs, whereas males are limited only by the number of females that they can find and seduce. So, he proclaimed with a flourish, males (including humans) are natural philanderers while females (again including humans) are naturally chaste—and in all but the most unusual circumstances should be indifferent or hostile to mating more than absolutely necessary. From this perspective, Twiggy, your mate's passion is weird and inexplicable: he should be off seducing other stick insects, not sticking stubbornly to you.

Nonetheless, this “men are cads, women are saints” hypothesis—more politely known as Bateman's principle—has been all the rage. Patriarchs have extolled it. Feminists have invoked it. Scientists have expounded it and buttressed it, adding extra reasons—the risk of venereal disease or being caught by a predator while copulating—why females would naturally want to keep sexual activity to a minimum. And certainly there are some species—such as the alfalfa leaf-cutter bee—where females mate just once. There are other species where males race from one girl to the next or are so eager they'll fornicate with anything: goldfish, for example, are occasionally drowned by amorous frogs. But as a general rule? Ha!

Bateman's principle has a fundamental flaw: it's wrong. In most species, girls are more strumpet than saint. Rather than just mating once, they'll mate with several fellows, and often with far, far more than necessary just to fertilize their eggs.

How did Bateman come to be so misguided? There are two reasons. The first is a quirk of fate. As I said, *Drosophila melanogaster* was—and remains—the most fashionable fruit fly to study. Females of this species really are quite restrained, preferring not to mate more than once a week or so. Other species of *Drosophila* would have given different results: *Drosophila hydei* females enjoy sex several times each morning, for example. But even in *melanogaster*, females are not as virtuous as Bateman thought. The trouble is—and this is the second reason he blundered—his experiments were too short. We now know that if he had continued them for one more week, he would have discovered that *Drosophila melanogaster* females recover their appetites—and indeed that those who mate only once have fewer children than their more lascivious sisters.

The reason it took more than thirty years for anyone to detect the problems with Bateman's theory is partly because his logic sounded reasonable. Moreover, it seemed to be supported by observation. Thousands and thousands of hours spent watching mammals and birds going about their lives had given no suggestion that females were often unfaithful to their mates. That's not the whole story, though. Even once scientists started to notice that females in some species—especially insects—do mate with a lot of males, they didn't immediately grasp the full implications. If females mated more than expected, it was assumed they had "malfunctioned" or that males had led them astray, not that females might have something to gain.

In the 1980s, the development of more sophisticated genetic techniques meant that biologists could find out who

was really having whose children. And they discovered something astonishing, something that no one had predicted. Namely that, from stick insects to chimpanzees, females are hardly ever faithful.

This discovery was swiftly followed by another that was even more surprising: in species after species, rampant promiscuity is no malfunction. Rather, females benefit from it. My files bulge with examples. To pick a few at random, female rabbits and Gunnison's prairie dogs both show higher rates of conception if they mate with several partners while they are in heat. The female sand lizard hatches out more eggs the more lovers she's had. The female slippery dick—a pale fish that lives on coral reefs—will have more of her eggs fertilized if she spawns with a gang than if she spawns with just one fellow.

These discoveries have forced a reevaluation of male and female behaviors that is still under way. But one conclusion is inescapable. As we shall see, when females mate with more than one male, War capers nimbly through the boudoirs, imps of discord frolicking in his wake.



Dear Dr. Tatiana,

My boyfriend is the handsomest golden potto I ever saw. He's got beautiful golden fur on his back, creamy white fur on his belly, he smells delicious, and he has ever such dainty hands and feet. There's just one thing. Please, Dr. Tatiana, why is his penis covered with enormous spines?

Spooked in Gabon

All the better to tickle you with, my dear. At least, I'll bet that's a big part of the reason. Golden pottos are little-known relations of bushbabies—small, night-climbing primates that are distant cousins of monkeys and apes. If you look at your cousins, you'll see your beloved is not alone. Bushbabies and many other primates have

monstrous penises—many of them look like medieval torture instruments. They have spikes and knobs and bristles and are often twisted into weird and sinister shapes. By comparison, the human penis is dull, notable only for its girth.

Penises are for more than just sperm delivery, you see. If females mate with a number of males, each subsequent suitor will sire a larger proportion of her children if his sperm are the ones that do the trick. A male who can stimulate his mate to take up more of his sperm, or who can somehow get rid of the sperm of his rivals, will spread more of his genes than less artful fellows. Thus, the first consequence of female promiscuity is that males are under great pressure to outdo one another in all aspects of love. For this task, the penis is an important tool.

Consider damselflies. These insects, close relations of dragonflies, look sweet and innocent as they flit along the riverbanks on a sultry summer day. But they have evolved some of the fanciest penises around. A typical damselfly penis has a balloon—an inflatable bulb—and two horns at the tip, plus long bristles down the sides. In the black-winged damselfly, *Calopteryx maculata*, the male uses this device to scour sperm from inside a female before depositing his own. But in the related *Calopteryx haemorrhoidalis asturica*, he uses his penis as an instrument of persuasion: by stimulating her in the proper manner, he can induce her to eject sperm from previous lovers. Meanwhile, the moth *Olceclostera seraphica* has genitals that resemble a musical instrument: the male rubs one part of his privates against another, producing vibrations with which to thrill his mate. In contrast, among termites the female typically mates with only one male—and male termites have plain, unadorned genitalia that do not differ much from one species to the next.

A penis is not the only way to outdo other males, of course. Take the ghost spider crab *Inachus phalangium*, a

creature that lives under the protective tentacles of sea anemones. The male makes a special jelly to seal the sperm of previous males into a corner of the female's reproductive tract so it won't be able to mingle with his own. Or consider the dunnock, a bird that looks like a sparrow that has fluffed its feathers in ashes. Most male birds—swans, ducks, and ostriches being exceptions—do not have penises. Instead, males and females copulate by quickly pressing their genital openings together. Hardly satisfactory. But even without a penis, male dunnocks have found a way to get rid of rival sperm. Before sex, the male pecks the nether regions of his mate; sometimes this encourages her to dump any sperm she's collected. Even more exotic: the red-billed buffalo weaver, an African bird that lives in small communities. The female is wildly promiscuous. Apparently in response, the male has evolved a pseudophallus—a rod of tissue that cannot transfer sperm. During sex, he rubs this rod against the female's genitalia for about half an hour—at which point he ejaculates from his genital opening and appears to have an intense orgasm. The male who provides the most vigorous stimulation is presumably the most successful at persuading a female to use his sperm.

All of this provides a clue as to why your friend's penis looks so alarming. Among primates as among insects, it is a rule of thumb that in species where females consort with one male at a time, penises are small and uninteresting. I mean, take the gorilla—a huge guy with a little teeny weenie. A male gorilla can weigh 210 kilos (460 pounds), but his penis is a measly five centimeters (two inches) long and entirely devoid of knobs and spikes. The Argentine lake duck puts him to shame. The duck is small, but his penis, which rivals that of the ostrich, is twenty centimeters (eight inches) long—and it has spines. But then, a male gorilla generally presides over a small group and does not often have to worry about other fellows' sperm. If I were a girl

gorilla, though, I'd feel I was missing out: as far as anyone can tell, the females of more promiscuous primate species are more capable of orgasm. So I'd guess your mate's penis is gloriously bespined because female golden pottos sometimes sleep around. But whether the spines have evolved because you like them or whether they are more for scrubbing—well, why don't you find out?



Dear Dr. Tatiana,

I'm a queen bee, and I'm worried. All my lovers leave their genitals inside me and then drop dead. Is this normal?

Perplexed in Cloverhill

For your lovers, this is the way the world ends—with a bang, not a whimper. When a male honeybee reaches his climax, he explodes, his genitals ripped from his body with a loud snap. I can see why you find it unnerving. Why does it happen? Alas, Your Majesty, your lovers explode on purpose. By leaving their genitals inside you, they block you up. In doing so, each male hopes you will not be able to mate with another. In other words, his mutilated member is intended as the honeybee version of a chastity belt.

You may think this is no way to treat a queen. But even queens are not exempt from the battle of the sexes. Indeed, I'm afraid your situation appears to exemplify the full, complex, and dynamic conflicts of interest that can arise as a consequence of female promiscuity.

To see how the conflict unfolds, let's first look at matters from the male's point of view. His plight is desperate. A young queen such as yourself spends a mere few days mating before going off to start a nest. After that, you'll never bother with sex again; you'll be too busy having your half million children. Worse, his chances of mating with you are small to start with. Honeybees have sex on the fly: you take to the skies and mate with any male who can catch

you. The competition can be fierce: as many as twenty-five thousand males may assemble to contend for a single queen. But you probably won't mate more than twenty times, so most male honeybees die virgins. Any male who succeeds in catching you has nothing to lose by exploding: he'd be unlikely to mate again anyway. What's more, he may have something to gain. If, by blocking you up, he can prevent just one other male from copulating with you, he will fertilize a larger proportion of your eggs—and more of his genes will be passed to the next generation.

But the problem is, while his interests are best served if you mate only with him, you do better if you mate with several males. Indeed, a queen who mated only once could be at risk of losing half her brood. Why? Because of the complicated way that gender is determined in honeybees.

Usually, male honeybees hatch from unfertilized eggs, females from fertilized eggs. But bees have a gene, known as the sex-determining gene, that can mess up this arrangement. If a queen mates with a male who has the same version of this gene as she does, then half her fertilized eggs will hatch out sons—and sterile sons at that. Thus, instead of producing a mixture of dutiful daughters working hard to rear their sisters and a few fertile males waiting for their once-in-a-lifetime opportunity to explode with joy, half her children would be good-for-nothing infertile males—which the dutiful daughters would eat alive. Such a reduction in the workforce increases the risk that the nest will fail. If, therefore, the queen mates with several males instead of just one, any male whose sex-determining gene matches hers will fertilize a smaller proportion of her eggs. This way, only that small proportion of her offspring will be sterile males. So the more a queen mates, the more likely she is to avert disaster.

That's not all. Males, obviously, will also gain if they can thwart previous lovers by removing the plug and mating with the female in their turn. You might imagine, then, that

male honeybees would have evolved some way of removing the chastity belt. You'd be right. If you look closely, you'll see that each male honeybee sports, on the tip of his phallus, a hairy structure that can dislodge the severed genitalia of his predecessor.

This suggests the following evolutionary scenario. Once upon a time, queens mated with only one male. Then a mutant queen appeared who mated with more than one. She was more successful at reproducing than her virtuous sisters, and the gene for multiple mating spread throughout the honeybee population. Then a male appeared who, by exploding, prevented the queen from mating again. Genes for exploding males spread throughout the population. In a counter-countermove, the queen evolved to block the male's advantage, either removing the plug herself or perhaps having it removed by the workers (this step would have happened swiftly, since any female who did not remove the plug would not have been able to lay eggs). Then males evolved their own counter-counter-countermove. And so on.

As you've probably guessed, such a situation is far from unusual. It is generally the case that whenever females mate repeatedly, males are sure to lose. Any male who can prevent a female from mating with his rivals will sire more of her children than a less controlling fellow and will thus spread more of his genes. So you shouldn't be surprised to learn that chastity belts are a popular evolutionary invention, in vogue among bats, rats, worms, snakes, spiders, butterflies, fruit flies, guinea pigs, squirrels, chimpanzees—I could go on. I must admit, however, that most of these fellows opt for the more traditional plugs, cements, and glues rather than for amputating their genitalia. In many species of rodent, for example, males have enormous glands to secrete tough, rubbery corks that they place deep in their partners' reproductive tracts as they finish copulating. The house mouse makes a plug so

tough that a scalpel virtually bounces off it; once the plug has formed inside a female, attempts to remove it can tear the ligaments of her womb.

But alas, poor males. Whenever repeated mating is beneficial to the female, she will gain by resisting male efforts at control. Thus, as males evolve to control, females evolve to resist. Which is why not all chastity belts are as effective as they might be. A female fox squirrel, for example, reaches around and pulls out the plug right after sex (and sometimes then eats it—how delicious). Moreover, males will also be under pressure to evolve to remove the plug. Again, this skill has appeared repeatedly. In the rat, the male's penis is almost prehensile: it can do some glorious gymnastic flips to dislodge plugs left by previous lovers, making like a toilet plunger and pulling them out with suction.

So you see, the battle of the sexes is fought on two fronts. Conflicts of interest between males and females mean that every new weapon or behavior evolved by one sex will favor traits in the other sex that can counter that development. At the same time, males evolve to manipulate and thwart a female's previous and subsequent lovers. If you watch through the generations, you'll witness a mighty evolutionary battle.



Men, you're in a cruel bind. Female promiscuity puts your genes at risk: it's no good seducing all the women in sight if none of them uses your sperm. A woman's potential for promiscuity curbs your own and exerts a powerful force on your evolution. Rather than maximizing the number of girls seduced—that is, acting like a cad—you should try to maximize the number of eggs fertilized. For some men, some of the time, this will amount to the same thing: more skirt chasing. On many occasions, though, cads who spread

their bounty will have fewer offspring than more loyal fellows, and so genes for pure caddishness will decline in frequency. Far better would be to attach yourself like the stick insect, explode like the honeybee, or evolve still other fates stranger than your strangest dreams.

•2•

THE EXPENSE IS DAMNABLE

IT'S NOT EASY being a male. Especially if you have to make sperm twenty times longer than you are. Or produce billions and billions of sperm in every ejaculate. Or copulate a hundred times a day to satisfy your partner. Or perform some other feat of prodigious sexual prowess.

Dear Dr. Tatiana,

I'm a splendid fairy wren, and I'm concerned about my husband. He keeps going to the doctor because he's convinced his sperm count is too low and we won't be able to have children. But he ejaculates eight billion sperm at a time, so I don't see how he can have a shortage. Has he really got a problem, or is he being neurotic?

Bewildered Down Under

The doctor, eh? I'd say your mate is not a hypochondriac but a liar. His "appointments" are a thin disguise for philandering. Splendid fairy wrens are notorious for their extramarital adventures. Let me give you a tip. You can tell when a fairy wren's going a-wooing: he'll be carrying a pink petal in his beak to offer to his paramour. Why pink? It looks pretty when he fans his iridescent blue cheek feathers.

But the real question is why a bird smaller than my fist should need an ejaculate containing more than eight billion sperm. In human beings, the average dollop contains only 180 million or thereabouts. Even that's odd when you think about it, though. All those sperm for one little egg. Why?

Sperm numbers are a crude index of the difficulty of reaching an egg. If you're a tree, for example, the amount of pollen you make depends in large part on how it gets delivered. Take fig trees. Some species are pollinated by virtuous wasps, wasps that actively collect and distribute pollen; these figs can afford to be frugal with the stuff. Other fig species are forced to rely on lazy wasps that just brush against the flowers; these figs are, perforce, profligates. So in species like yours or mine, where a male delivers his sperm personally, you would imagine that sperm counts would drop.

Not necessarily. In some species—of fish, for example—males and females meet up, but instead of copulating, they spawn eggs and sperm into the water. And yes, in such cases sperm do not dramatically outnumber eggs. But when you turn to birds, mammals, and other groups that copulate, the picture changes. Instead, you find that males make the most sperm in species where—drumroll, please—females are sluts.

Two factors are thought to produce massive sperm counts in species where the girls are promiscuous. The first is what biologists call “sperm competition”—that's right, sperm from different males vie with each other to fertilize eggs. If sperm competition proceeds according to a raffle—the more tickets you buy the more likely you are to win—then the males that produce the most sperm will have the best chance of fertilizing a female's eggs. And if the number of sperm they make has a genetic basis, then over time the repeated success of males with the highest sperm counts will lead to an increase in the number of sperm each male produces. Reflecting this, males regularly exposed to sperm competition should also have larger testes—sperm factories—for their body size. Indeed, an experiment with yellow dung flies—hairy flies that mate and lay eggs on fresh cowpats—has shown that testes size can evolve in

response to sperm competition in as few as ten generations.

Carrying the argument to its logical conclusion, then, males who are never at risk of sperm competition should produce only enough sperm to fertilize each egg. Unfortunately, few fellows are in this luxurious position. But males in one group are—seahorses and their close cousins, pipefish. (Pipefish look like seahorses that have been straightened and streamlined.) These males are famous for their pregnancies. Females typically deposit eggs in the male's brood pouch, and he fertilizes them there—so there's no chance of his sperm encountering those from another male. Most species of seahorse have not had their sperm counted. But one that has is the seaweed pipefish, a species common in sea-grass beds around Japan—and sure enough, his sperm count is vanishingly low.

The second factor thought to produce high sperm counts is that sperm die in huge numbers on their travels through the female reproductive tract: of the millions that set out, just a few succeed in reaching their goal. Fantastically high sperm death has been remarked upon for more than three hundred years, yet there is still no good theoretical explanation for why so many sperm die in the first place.

You see, the surprising fact is that female reproductive tracts are often hostile to sperm. No one knows why this is so. But rather than cosseting sperm and helping them on their way as you might expect, reproductive tracts are full of hazards and treachery. Sperm may be digested, ejected, or rounded up and removed. Even in species where the females store sperm for years, they only keep a few of the sperm that they get. A honeybee queen who mates with seventeen lovers, for example, will receive an average of 102 million sperm (6 million from each fellow); yet she'll keep a mere 5.3 million to fertilize her eggs. In species that don't store sperm—it's carnage.

In humans, for example, sperm start their odyssey in the acidic environment of the vagina. But acid is lethal to sperm (which is why strategically placed lemon slices make a good, if rudimentary, contraceptive), and fewer than 10 percent will continue their onward voyage. Survivors must then traverse the cervix, a barrier coated with mucus that even at the best of times permits a mere 10 percent of sperm to cross. Mucus is only one of the cervical hazards, though. At the first hint of sperm, white blood cells—the foot soldiers of the immune system—swamp both the cervix and the lining of the womb and destroy any intruders they encounter. In rabbits, within an hour of copulation an enormous army of white blood cells assembles at the cervix; in women, the army amasses within fifteen minutes of copulation, and within four hours it numbers more than one billion. By the time sperm reach the fallopian tubes—the place where any fertile eggs might be hanging about—their numbers will have dwindled from millions and millions to a few hundred. Which is why men with a sperm count of fifty million—which might seem generous—are likely to be infertile.

Measuring hostility is much harder than counting sperm, so we don't know how hostility varies among species or even among individuals of the same species. I would guess, however, that females respond to escalating sperm numbers by increasing the hostility of their reproductive tract. This in turn would favor males who produce more sperm. In the rabbit, for example, the number of sperm arriving at any given stage of a female's genital tract depends on how many sperm started out. But what do females gain from being hostile? After all, it seems counterproductive: if they are too hostile, their eggs won't be fertilized and they'll have no children. One idea is that hostility ensures that only the most superior sperm succeed in fertilizing eggs. Another is that hostility may initially evolve as a defense against infection. This would then be

met by male attempts to bypass the defenses. Indeed, the semen from humans and many other mammals contains substances known to suppress the female's immune response. To counteract male attempts at suppression, females may respond by increasing the magnitude of their immune response—setting up an escalating evolutionary cycle of response and counterresponse.

Which brings me back to why your husband needs so much sperm. In splendid-fairy-wren societies, couples live together and rear children together—but free love prevails. Splendid fairy wrens are splendidly promiscuous, and most females have at least one lover as well as a husband. As a result, sperm competition is intense. Often, none of the chicks in a nest will have been sired by the male who is rearing them. So while your husband is off philandering, perhaps you've engaged in a little mischief of your own?



Dear Dr. Tatiana,

*I've heard it's going to take me three weeks to make just one sperm. Apparently this is because it's going to need a tail twenty times longer than my whole body. This seems awfully unfair: I'm just a little fruit fly, *Drosophila bifurca*. Can't I get a prosthesis?*

Waiting for Sperm in Ohio

There's no market in artificial sperm tails: you're going to have to make them yourself. You're right—it's not fair. Why should a fruit fly three millimeters long—smaller than this dash—have to make sperm that measure fifty-eight millimeters? A human is far bigger than you, but gets away with sperm one thousand times smaller. Indeed, if a man were to make a sperm on your scale, it would be as long as a blue whale. Now, that I'd like to see.

Unlike sperm number, the evolution of sperm size and shape is something we know little about. All we can say for