THIS SECTION WAS ORIGINALLY PART OF CHAPTER 3 ("THE ANATOMY AND PHYSIOLOGY OF LIVING IN THE WATER"). AS A WAY OF ILLUSTRATING THE LOGIC BEHIND THE ADAPTATIONS ANCIENT CETACEANS HAD TO MAKE TO LIVE SUCCESSFULLY IN THE OCEANS, THIS DISCUSSION TAKES UP THE QUESTION, "IF HUMANS HAD TO ADAPT TO LIVING IN THE OCEANS, HOW WOULD OUR BODIES CHANGE?"

## Adaptations to living in the water

The rule in nature is "survival of the fittest." Many humans use this phrase as though it were "survival of the meanest." But "survival of the fittest" in fact means survival by those organisms (big or small, plant or animal) that have the greatest capacity to "fit into" their environment in a way that increases the odds that they and their descendants will survive. Species that can cope with the vagaries of life—find food and water, avoid predators, resist disease, deal with hard times and adjust to changing conditions—will survive. Those that can't become extinct. In the end, Mother Nature is a pragmatist. The only thing that counts is what "works."

Even though dolphins started like us—as land mammals—they look the way they do mainly because they had to adjust to surviving in the water, and less because they come from a different part of the animal kingdom. Going from a furry wolf-like, hoofed creature to a sleek ocean dwelling cetacean obviously required many major adaptations throughout the evolutionary process. The "alien" body of a dolphin didn't happen overnight. It's a function of millions of years of adapting to the specific conditions in which dolphins lived. That is, the anatomy and physiology of the modern dolphin is a function of adjusting to the differences between living on land and living in the water. Water is denser than air. It transmits sound better than light. It mutes the effect of gravity. It draws heat away more quickly than air does. It allows for some technologies, but makes others impossible. The body of a dolphin is the "logical" response of a species that goes from the land to the water. It's the result of a dynamic process—the interaction between an organism and the environment in which it's trying to survive—that ultimately reveals a successful formula.

## <u>An exercise in imagination: human adaptations to the water</u>

The logic that governed the transformation of ancient cetaceans from land dwellers to ocean dwellers is efficient survival in the water. Every change had a purpose, and the design of the dolphin body was its ancestors' response to the challenges of surviving in the ocean. In order to appreciate the details of the logic involved and to understand better the dynamics of surviving in the water, let's try an unusual intellectual experiment. Imagine that all of the discussion about global warming has, in fact, colossally underestimated the problem. In reality, the temperature of the planet is going to climb so high that over the next few centuries the polar ice caps will completely melt and the small amount of land remaining won't be able to sustain any crops. Also assume that, for one reason or another, it's going to be impossible for us to create floating communities that would let us preserve our land based technologies. The bottom line is that ultimately it's going to be just us and the oceans. Humans will have to return to the water if our species is to survive. How would our bodies have to change? What adaptations would the "logic of survival" dictate for the human body? [1] The answer to this question will actually teach us a good deal about dolphins.

There are a number of reasons why it's important to take this imaginative exercise seriously and to understand the forces involved in fashioning a dolphin's body. First, the interaction between an organism and its environment affects more than physical traits. Most of us tend to overlook the fact that a

1 The changes that we're going to describe in the following short and elementary discussion would, of course, take many generations. The point of the exercise is simply to explore the logic that would underlie such a long, slow process. The way that "natural selection" works is that beings with physical traits that give them even a tiny advantage of surviving in their environment pass those traits on to succeeding generations. Natural conditions encourage their development so that they eventually become more pronounced over thousands of years. For example, early cetaceans with more body fat and a good physiology for swimming survived better than cetaceans without these traits. They had children with these traits, and the dynamics involved in surviving not only kept these traits in the gene pool, but rewarded mutations that made them even more pronounced. Charles Darwin describes the process in *The Origin of Species* as follows: "any being, if it vary however slightly in any manner profitable to itself, under the complex and sometimes varying conditions of life, will have a better chance of surviving, and thus be *naturally selected*. From the strong principle of inheritance any selected variety will tend to propagate its new and modified form."

species' environment also molds social, emotional and intellectual dimensions as well. When we examine dolphin intelligence, social and emotional life later in this book, we'll see how these parts of their lives are also shaped by what it takes to survive in the water. And we'll conduct other versions of this exercise in those chapters by asking what intellectual, social and emotional adaptations humans would have to make if we went back to the water. Since those versions of this exercise are going to be more theoretical and speculative, it's important to understand the logic involved in the easiest and most obvious part of the process—the physical.

More broadly, however, most of us probably have an inaccurate picture of the way our planet—and the life on it—operates. Despite the annual cycles of the weather, the ebb and flow of the tides and terrifyingly unannounced natural disasters, most of us experience the Earth as a relatively static place. Because we experience so little of the dynamic quality of the planet's life first hand—global climate change, continental drift, evolutionary leaps in the life of a species—it's understandable that we have a false picture of reality. After all, even though you might feel as though you're sitting still at this moment, you know that *in reality* you're moving as the Earth makes its daily rotation. Depending on where you live, you could be going as fast as 1,000 m.p.h. Add to that the forward motion of the planet (about 66,000 m.p.h.) as it travels around the sun and the additional movement of the solar system (about 45,000 m.p.h) and of our galaxy (about 1.35

million m.p.h.) as we hurtle through space propelled by the force of the original "Big Bang," and you know that any sense of "standing still" is an illusion of enormous proportion. Still, our everyday senses tell us exactly the opposite. So it's no surprise that our unreflective sense of the world is that, for the most part, it's a fairly stable place. We might say that despite what we all know about physics, we think like "un-physicists" most of the time.

When it comes to discussing the living beings on the planet, most of us have an everyday, unreflective mind-set that's the equivalent of our "un-physicist" attitude that "I know the Earth is moving, but as far as I'm concerned, I'm standing still." We may know that every species has an evolutionary history and that every feature of every being has a purpose and has developed as a result of the interaction between that species and its environment. But, for the most part, when we're curious about something in the world of biology, we set all that aside and become "un-biologists." That is, we're content with explanations that are essentially unsophisticated and superficial descriptions of the world of nature just the way it is today. To oversimplify things: tigers have stripes, leopards have spots, dolphins live in the oceans, humans live on land, we have two eyes, two ears, a nose, a mouth, four limbs, hands, feet, internal organs, and so on. Things are just the way they are. There's no history—no process.

The problem with this way of describing reality, however, is that it's only a small part of the picture. As "un-biologists" we fail to look at *why* things are the way they are—how they became that way. And in failing to understand the details of the process that produced all of the elements of the natural world around us, we fail to recognize the great complexity and purposefulness that operates in the natural world. Dolphins didn't just end up the way they are by accident. Neither did humans. Both of us are products of natural forces and conditions that evoked certain traits and adaptations.

It's critical to understand that the shape of living things is the outcome of the *relationship* between species and their surroundings. That is, we're the product of the *interaction* between organisms and an environment. Actually, although this may be something of an exaggeration, it's not entirely different from a chemical reaction. If we combine specific proportions of oxygen and hydrogen at a certain temperature, we get water. But if we use carbon instead of hydrogen, and if we lower the temperature, we get dry ice. Change the conditions; change the outcome. Biological change may work at a m-u-c-h slower pace than chemical reactions do, but both involve reactions of one sort or another—except biologists call them "adaptations."

Dolphins returned to the water while we've remained on land. Therefore, the adaptations of our respective species are products of very different natural forces and conditions. The general principles may be the same on land and in the water—survival and adaptation. But the details are different because living in the water and living on land are so different. For example, consider something like the simple idea of "moving with efficiency." Humans came to accomplish this with an upright posture, two legs and feet. Dolphins achieved it by a hydrodynamic shape and a tail fluke. We use different mechanisms to move because the details of what produces efficient motion in these two environments differ.

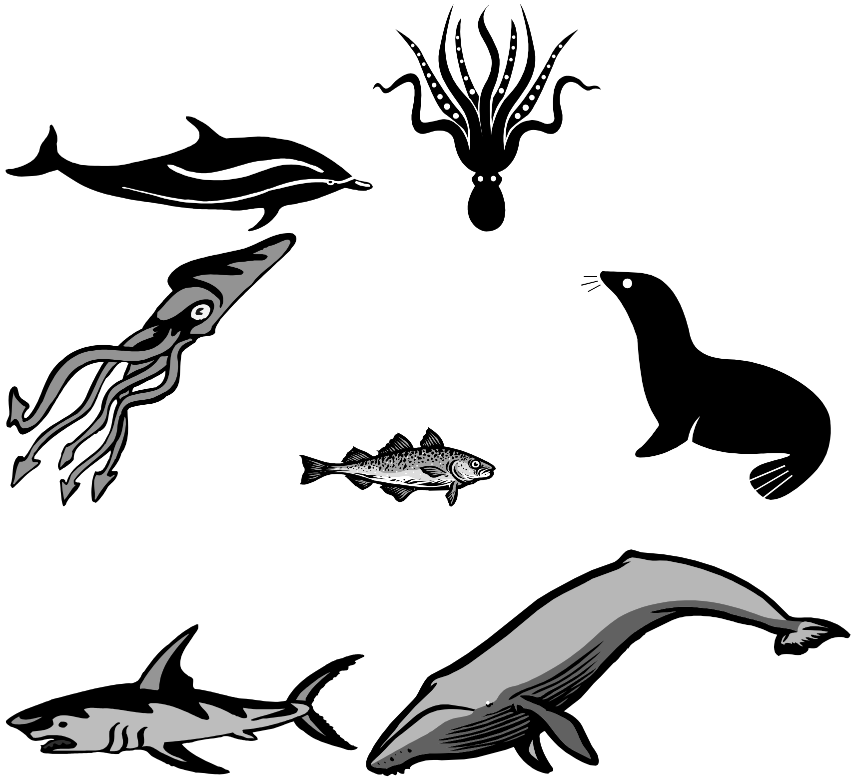
But what about something more complicated like "behaving with intelligence"? Is it possible that the land and the oceans might produce differences here? After all, "intelligence" isn't some amorphous property magically infused into us. It's a complicated series of capacities and behaviors that develops in response to certain stimuli or conditions. But if we change conditions, would the outcome change as well? In short, could there be some significant differences in how advanced properties like "intelligence" or "complex communication" manifest themselves on land versus how they appear in the ocean? In the same way that something like "efficient motion" has, shall we say, a "species-specific" or a "context-specific" definition, could the same be true of more complex properties?

We'll explore these questions later in this book, but for now we need simply to appreciate fully the relationship between species and the environments in which they developed. If not, we risk making the anthropocentric mistake of trying to understand dolphins only in terms that apply to our species or to the conditions that produced our species. And this would lead to misunderstanding, misinterpreting or not even recognizing some important differences between humans and dolphins.

Back to the sea: bodily adaptations

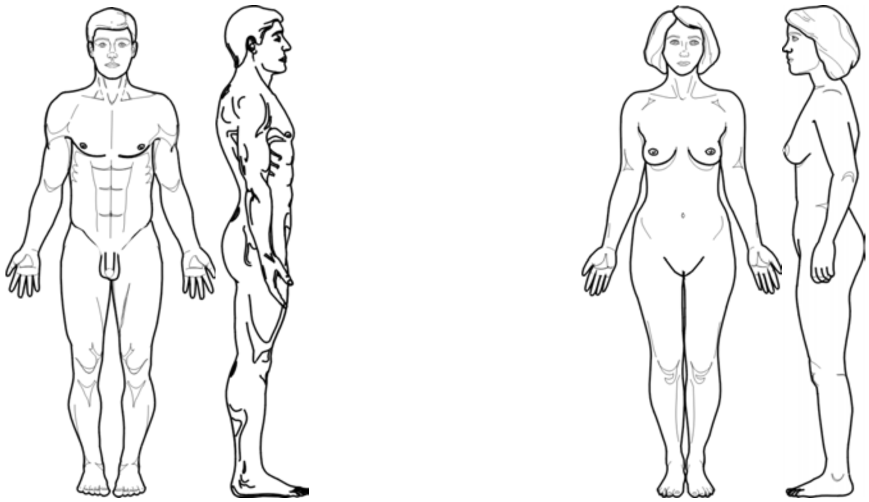
So, if humans returned to the seas, how would we change? What adaptations would result from the interaction between the human body and a watery environment?

At first, you might think that if humans adapted to living in the water, we'd end up looking like mermaids and mermen. But this guess would at best be only half right (the bottom half).

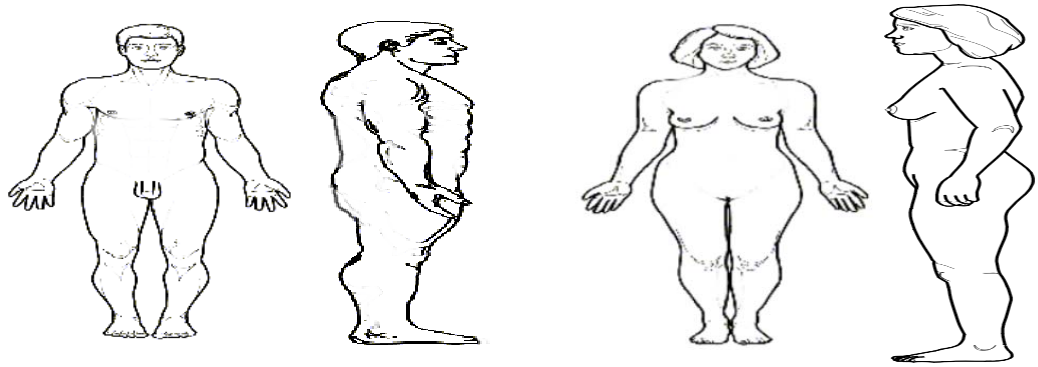


Look at the shapes of the ocean's swimmers—small fish, sharks, squid, whales, dolphins, and seals, for example. Focus on the similarities, and notice these beings look nothing at all like "merpeople." That's because the physical properties of water determine the most efficient shape for motion through the oceans—in the same way that the physical properties of air determine the best shape for anything moving through that medium. So you can expect that the "logic of the water," we might say, would determine that humans would ultimately look more like the other citizens of the deep than the way we do now.

We can assume that if humans were to go back to the water, our clothes wouldn't last very long.



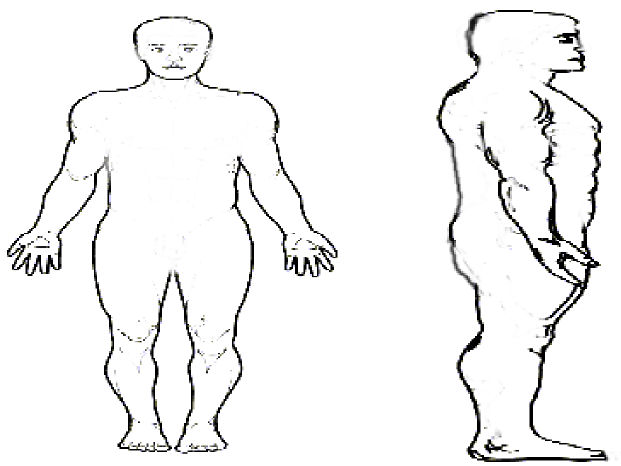
So one thing we'd need to do is to figure out how to stay warm. Water draws heat out of a body much more quickly than air does. If the air temperature is 50 degrees, it's no big deal. But 50 degree water is life threatening—we can survive in water that cold for only a relatively short time. If our core body temperature drops to 85 degrees, it's usually fatal. So, we'd have to produce a biological version of neoprene, the material out of which wet-suits are made. Fortunately, we have that ability. Our bodies store excess calories as fat, so we'd just have to eat enough to develop a good layer of blubber. Rail-thin supermodels and buff bodybuilders with 3% body fat wouldn't survive very long, so our species would definitely head in a "Reubenesque" direction. A much higher level of body fat would be the norm. Since we have the ability to grow hair, it's possible that we'd also end up growing pelts, the way that the fur seals do. But for the sake of this exercise, let's just assume we pack on a layer of blubber.



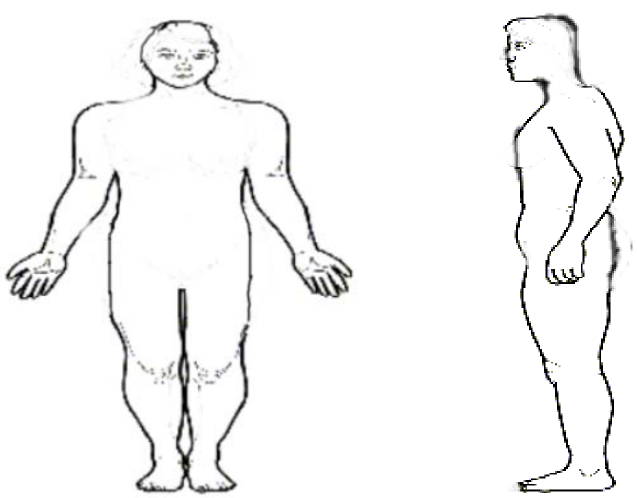
Staying warm would also be easier if we could reduce the surface area of our bodies. If a cold breeze starts blowing over you as you're in bed and you don't want to get up to get a blanket, you don't splay out so that your arms and legs are more exposed to the wind. Instead, you pull your limbs together and curl up into a ball to make yourself a smaller target. By the same token, if there's less skin exposed to the water, we're going to lose less heat. Keeping our legs together and holding our arms against our bodies as much as we can while we swim are probably good places to start.

Of course, making ourselves more compact will also make us more streamlined, and this will help us move through the water more efficiently. Airplanes, race cars, Olympic sprinters and professional cyclists may look for ways to become more aerodynamic, but most of us don't think twice about how we move through the air. Swimming through the water is a different story, however. Because water's so much denser than air, the more "hydrodynamic" we could get, the better. The more streamlined we are, the faster we can move with less energy. A well-insulated, streamlined form will need less food than our current bodies would need to survive in the water. This will let us go longer between meals—something that could come in handy on days we can't find fish. This will also let us be more agile in the water—definitely useful not only for catching our own lunch but also for avoiding becoming something else's.

Over a long period of time, the advantages of being hydrodynamic would probably produce some interesting changes in the human body. Because unnecessary bumps and bulges would only increase drag in the water, nature would have to do something about ears, prominent noses, breasts, “hourglass” figures and male sexual organs.



Male

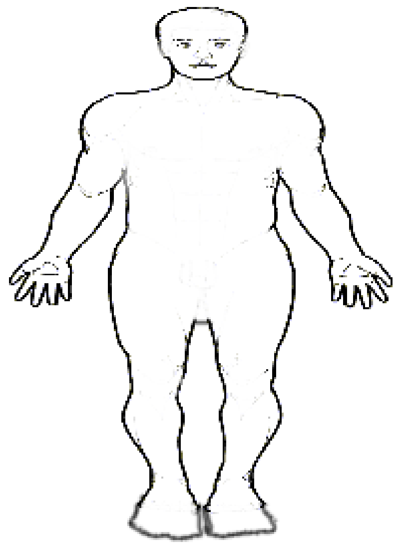


Female

The need to power ourselves through the water would also produce some changes.

- Because we expend less energy pushing something rather than pulling it (the reason that submarines put their engines in the rear), the large muscle groups in the bottom half of our body (gluteals, hamstrings, quadriceps, calves) would become our main source of power. So they'd probably develop more.

- The more surface area we can kick with, the better. So big feet would be better than small feet, and huge feet would be better yet. It would also help if our toes got a lot longer and if the skin between them grew so that our feet would be more webbed. It would help if our feet could end up more like the swim fins that divers use.



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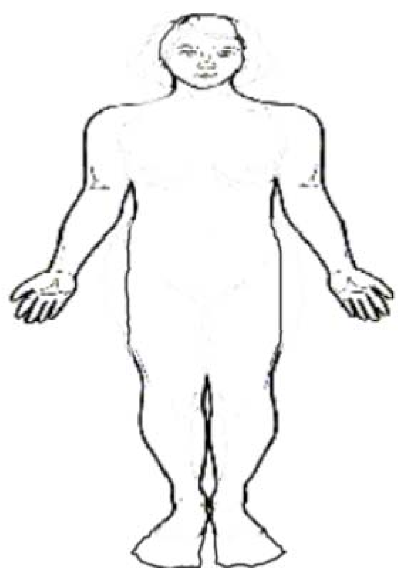
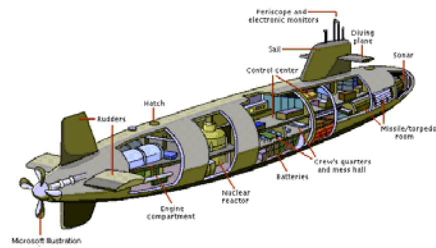
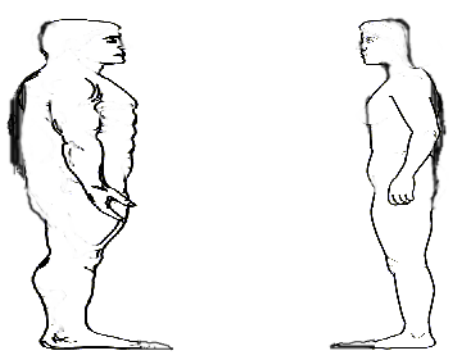


Female

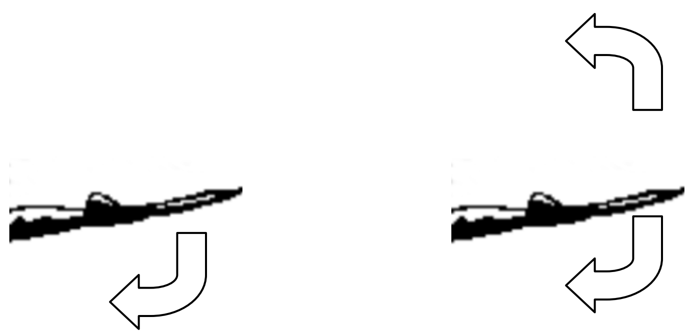
To stay balanced while we swam and to control our direction, we'd also need some biological version of a boat's keel and rudder. Or, actually, a better comparison is that our bodies would need something equivalent to the devices that airplanes use to control the different ways they move: fin, rudder, flaps, elevators, ailerons.  We're going to do a better job of surviving in the ocean if we can swim well underwater, and that's as much a three-dimensional challenge as flying is.  Indeed, it's no surprise that airplanes and submarines share some similarities in their design.


We don't currently have anything that can serve as a keel, but seals and squid do all right without one, so we might be able to as well.  However, the prevalence of dorsal fins in the oceans suggests that humans with pronounced spines would probably have an edge.  So we'd probably see at least a spinal ridge develop.

Male  Female

Since our ankles are pretty flexible, we should be able to use our feet as rudders.  However, any of our descendants who can get a wider range of motion in their ankles would be better off because they could control the speed and direction of their swimming better—in the same way that the elevator and flaps of an airplane do.



Current range of motion Better range of motion

To get this kind of rotation, the ankle joint would have to change dramatically so that it would be more like the ball and socket arrangement we find in our shoulders and hips.  And that's a pretty involved adaptation.  There is, however, another way of achieving the same end—we get rid of the joint altogether.  Actually, this is not only simpler, but it's more likely to happen in the water.  Do you know what happens to men and women who spend extended periods of time in space?  Their bones become less dense and they lose muscle strength. Why? Because of weightlessness. The human skeletal and muscle systems evolved to counteract the force of gravity. Remove gravity, and these systems don't have the same job to do. And since the rule in nature is "use it or lose it," the bodies of people who spend time in zero gravity respond accordingly.

The ocean may not be weightless, but its buoyancy significantly reduces the force of gravity. So this suggests that the human skeleton and muscle systems would undergo some changes. We can assume that bones would get weaker from the decreased impact of gravity. But in addition, the more of our skeleton we lost, the faster we could move in the water. We may need both strong bones and strong muscles to move quickly on land, but in the water, the muscles would definitely be more important. Lots of our bones would simply be dead weight.

Bone density will drop, and our skeleton will change. Bone loss in the bottom part of our body might actually lead to our legs fusing. I can tell you from personal experience that if you're trying to move around under water while "freediving," it's often easier if you kick your legs together (the "dolphin kick" that butterfly swimmers use) rather than alternate them (the "flutter kick").[2] So, a unified set of muscles, rather than two separate limbs, would allow for more power, particularly if our feet evolved into something that looked like a monofin.

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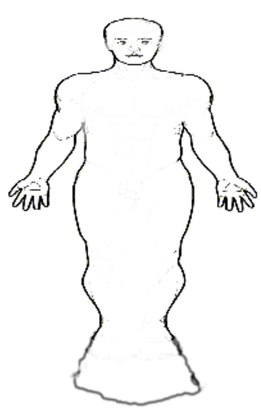
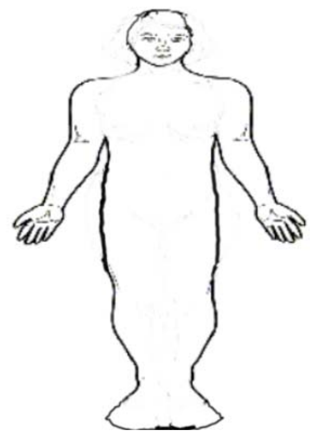
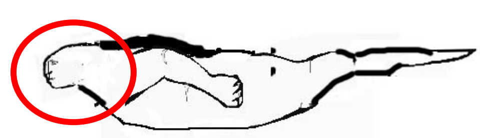
[2] "Freediving" (also called "breath hold diving") is diving with just the air you can hold in your lungs. Because you aren't encumbered by oxygen tanks, you're much more flexible in the water.

Male   Female

Our head and neck would probably also change—as would the way we held our body. The current design of our neck and head isn't especially streamlined, and our natural posture would have us looking down. Life would definitely be easier if our head faced straight ahead and if our entire body was horizontal in the water. Perhaps we could maintain or even increase our neck's flexibility so that we could more easily look in different directions. In order to avoid taking in water while we're diving, our nose would probably take a different shape and have nostril that closed off. There's probably a good chance that our head would resemble a seal's.



It's hard to know what would happen to the rest of our upper body. Our rib cage would still serve to protect our lungs and heart. But what about our arms and hands? They're our best bet for ensuring some forward stability, but notice that none of the sea creatures in the figure above have the equivalent of human arms. Squid and octopi have tentacles, but they extend backwards when these animals swim. Any limbs that fish, sharks, seals or whales have on the top half of their trunk—or the equivalent structure on a submarine (the diving plane)—are relatively small. This tells us a couple of things about what "works" in the ocean. It suggests that the top half of our current bodies isn't hydrodynamic. It also suggests that our arms would probably change significantly. The fact that our current arms give off a good deal of heat in the ocean makes them an "expensive" appendage. They'd cost us a good deal in terms of calories, and the process of adaptation is going to preserve them only if they're worth the expense. Better-insulated arms, however, would be less useful because they'd be harder to move. They'd be heavier and offer more resistance in the water. Could they justify their continued presence in the body? It's difficult to say—particularly if the density of the bones in our upper bodies decreases. If we kept them, maybe they'd end up more like tentacles than limbs with bones.

What about our hands? This is a particularly interesting question because the human hand is one of the two organs (the brain being the other) that humans often cite as proving our biological superiority over all other beings. For example, it's not unusual to hear humans brag that we are the only beings with an "opposable thumb"—and hence the only beings who can use tools.[3] The ocean, however, doesn't provide as much raw material that can be used to make tools as the land does. And only if we continue using our hands for detail work and finely controlled movement will we keep the flexibility that we now have. Still, arms and hands are marvelous devices in their own right for reaching, grabbing and holding things. And because of our shoulder's ball and socket design, our arms and hands help us swim faster on the surface. So there are various ways that they'd contribute to our survival.

What ultimately happens to our arms and hands would probably come down to the relative importance of: making and using tools, reaching, grabbing and swimming. If we used tools for hunting or some form of marine agriculture and for defending ourselves, maybe we'd remain much as we are now. However, if you've ever tried to grab something in the water, you already know that our arms and hands don't move as quickly as they do on land—so they may not be as useful as we'd like them to be. (Depending on what we settle on to eat, maybe we'd find it more efficient to start grabbing things with our teeth.) If swimming on the surface gave us more of an edge in surviving, then the skin

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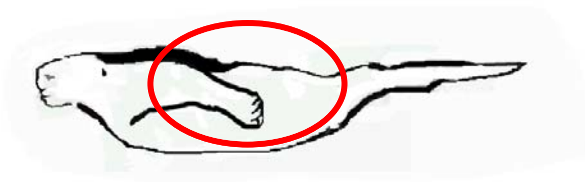
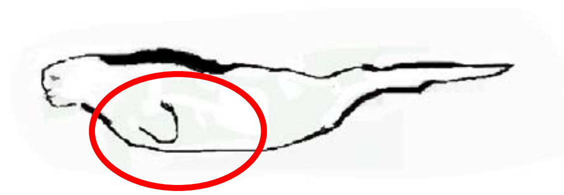
3 An "opposable" thumb can reach across the hand opposite all of the fingers and used for grasping small objects. For the record, humans are not unique in having an opposable thumb. The lemur, a primitive primate, also does. Moreover, humans are not unique in using tools. Chimps and dolphins do too.

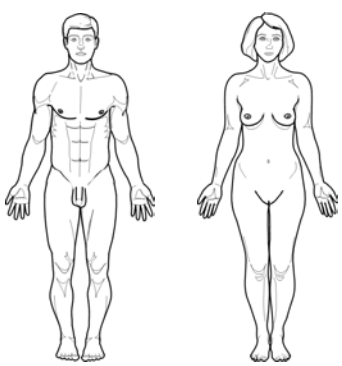
between our fingers would probably develop and our hands would become webbed. But if swimming underwater were more important, our arms and hands would probably get much shorter and be used mainly for steering.





Finally, our coloring would change so that we would be less visible to predators. Following one successful pattern in the oceans, we might change so that we're lighter on our underside and darker on our backs. That way, if something is looking at us from below, we'd blend into the light surface; and if something is looking at us from above, we'd blend into the dark below.

So our bodies would definitely change.  We'd start out looking like this.



But we'd probably end up looking something like this.

Behavioral adaptations

In addition to the way that the design of the human body might change, living in the water would also lead to some changes in our habits and behavior. Despite the fact that we'd be surrounded by water, getting fresh water would be a challenge. We can't survive on salt water, so we'd have to be eating food with water in it—a good reason for a diet of fish. Speaking of fish, we'd have to learn to hold our breath for much longer periods than we do now if we're going to dive down to catch them. But if we want to go very far, our bodies would have to adapt to the pressure. With every 33 feet, the pressure increases by one atmosphere. By the time we get a couple hundred feet down, we're going to feel about 7 atmospheres pushing against our chest. And at a certain point, the pressure is enough to crack our ribs.

Sleeping would become a huge problem. While extended periods of conscious rest would probably recharge our bodies, our brains currently require the unconscious states in sleep to function properly. But how would we sleep in the water and breathe easily? And even if we could figure it out, living in the water isn't like living on land. There's no place to hide from predators, and the nights are a particularly active time in the ocean.

Finally, we'd somehow have to deal with the fact that, as a rule, visibility is limited in the water. Even in the clearest waters, visibility is restricted to a couple hundred feet. To complicate matters, as you dive down, colors rapidly disappear, and the darkness grows. Just past 1,000 feet, the light's gone altogether. We'd obviously have an easier time if we could navigate in the dark.

There are many more fine points involved in the process of adaptation that we could look at, but I'm sure you get the general idea. If humans were able to make the transition from living on land to living in the sea, by the time the process played itself out over thousands of generations, we'd look and act very differently than we do now. In short, we'd be more like the current inhabitants of the ocean—not "merpeople." In fact, it's fair to say that we'd evolve into a completely different species: *Homo sapiens aquaticus*. And this species might actually look something like dolphins.