Ask A Biologist Vol 053 (Guests Dale DeNardo and Arno Vlooswijk)

Keeping Your Cool - Thermoregulation

How are some animals keeping cool and staying warm? Listen in as Dr. Biology talks with biologist Dale DeNardo and engineer and thermographic artist Arno Vlooswijk about thermoregulation. Could there be lessons for humans to learn from these animals?

Transcript

Dr. Biology: This is Ask-a-Biologist, a program about the living world and I am Dr. Biology, unless you're about you. But, this has been a really long summer and where I live it's a really long hot summer. We're talking about 110 degrees Fahrenheit which is 43 degrees Celsius. Now, for us humans there's air conditioning. Thank heavens, because if we didn't have it we'd be in bad shape. But, what do animals do that, say, live in the desert? How do they keep cool? By the way, the word that biologists like to use for controlling temperature is thermoregulation.

When talking about controlling body temperature, we want to answer a few questions. And one of them is, how could we learn from animals to thermoregulate our environment so that it's easier for us to keep our cool.

To answer this, we have two guests to talk about thermoregulation. Dale DeNardo is a professor in the ASU School of Life Sciences. He works on a really, really interesting animal that's pretty cool. At least, it's able to keep its cool even in the hot desert. It also has the look of a prehistoric monster lizard and, maybe, where it got its name, Gila monster.

My other guest is Arno Vlooswijk who is talking with us from Sint-Oedenrode in the south of the Netherlands. Arno has over 10 years experience in all kinds of energy, innovation and waste related projects. He thinks the way nature solves heat and cooling problems are something we should be looking into.

He also has a very cool project. It's a website called World of Warmth where he has along with other content some great animal thermographic pictures, which are a creative way to help understand thermoregulation. You can literally see what's hot and what's not.

A warm welcome to the show, Dale.

Dale DeNardo: Glad to be here.

Dr. Biology: And Arno, I really appreciate you chiming in from clear around the world in the Netherlands.

Arno Vlooswijk: Yep.

Dr. Biology: For the geographically challenged like myself, I had to go to the map and make sure I knew that if I'm not leaving England and going to the west to see Ireland, I'm going to be heading out to the east and going to, yeah, the Netherlands.

Arno: Small and dry and sunny at the moment.

Dr. Biology: Oh, so what's the temperature there now?

Arno: Well, it should be in degrees here, 23-24.

Dale: We'll get there in December.

Dr. Biology: Yeah [laughs]. Why I think you're talking Celsius, though, aren't you?

Arno: Yeah, I am.

Dr. Biology: OK. Dale, since we're talking about thermoregulation, and we're talking about thermoregulation in animals, which we are what are some of the basic things we need to know?

Dale: Well, first off, we need to know just like most processes that animals have, temperature regulation has to be kept within a set limit. And we tend to call this homeostasis, meaning the boundaries that we can have things fluctuate a little but not too far, whether that's our body temperature or blood glucose levels or anything else. When we talk about temperature in animals, we tend to divide them into groups: cold-blooded and warm-blooded animals. And those are awful terms, and that's one thing we're going to get out of this is eliminate those terms because most animals, most vertebrates especially, like their body to be relatively warm, and they want to keep it controlled.

The difference is that birds and mammals and what we call endotherms, meaning they produce quite a bit of heat from metabolism just the machinery of their body working and, therefore, they can heat their body through internal mechanisms. That's what we do.

However, other groups, such as reptiles, amphibians and fish, do not have that furnace inside, but they do have a thermostat and they do want to keep warm. They want to keep within a range, but they just don't have the furnace to heat themselves. So, what they need are external sources, either the sun for radiant heat or a warm rock, which would conduct the heat, but they both have the goal of keeping warm. It's just whether the heat source is internal, endotherm, or external, ectotherm.

Dr. Biology: And your Gila monster is actually an ectotherm.

Dale: My Gila monster is definitely an ectotherm which, for desert species, that's not a big deal because that's one thing that there is plenty of out there in the desert it's heat. So, why waste energy to produce a lot of heat when energy is limited? There's not a lot of food out there. The heat's free and save your energy because you're not getting a lot of food.

Dr. Biology: Ah, so I often see the little lizards around here sunbathing on rocks.

Dale: Exactly, they're just taking advantage of that free heat, and that's why in deserts there's much greater species diversity among lizards and snakes than there are among mammals because mammals take a lot of energy to work. We're eating three meals a day. My Gila monster can get by on two or three meals a year.

Dr. Biology: Two or three meals a year?

Dale: Yeah, but realize their meal is eating about a third of their body weight. So, it's like me taking down four or five turkeys.

Dr. Biology: [laughs] OK. Well, Arno, you and I are going to have to stick with three meals a day, aren't we?

Arno: [laughs] Yeah.

Dr. Biology: So, we're talking about this Gila monster, and my question is, how do these animals keep their cool? Are they just hanging out in the shade all the time?

Dale: Well, a couple things is I want to clarify with the name, Gila monster, that hey are lizards, the largest lizard in the United States and one of few venomous ones in the world. But, the interesting thing is just because they live in the hot desert, they don't prefer to be hot. They actually have a relatively low preferred body temperature which is about 29-30 Celsius, about 84-85 degrees Fahrenheit. So, they prefer to keep relatively cool, and to do this when it's hot during the hot months they come out only at night, and they stay underground during the day. Underground is a great place to be to avoid heat. They can vary their depth of how deep they go. As you go deeper in the ground, it can actually be cooler.

So, they can make adjustments. When they're underground, it doesn't mean they're just sitting there sleeping, but they can move up and down to get that temperature they want. The problem with staying underground, which they will do and they can do weeks on end, if needed, is the food's not underground.

They eat the contents of nests, bird eggs, small mammals, nestlings. And so, you can't wait for an egg to roll by your burrow. You have to go out and look for this egg. So, it means they have to come out, get exposed to hot temperatures, and it's dry so they can lose a lot of water.

They have various adaptations physiologically that they adapt to this. One is they can actually use their bladder. Their urinating bladder is a canteen. They can carry this water around with them, and normally what we put in our bladder goes one way, hopefully, in the toilet or something, but these guys can actually re-absorb the water component of that urine back into their systems. They use it just like a big water bottle that's inside of them, and this is extremely valuable. And we've shown if they didn't have that water bottle they'd never make it through our dry summer. This water bottle is critical to their survival.

Dr. Biology: OK. And the upper range of their body temperature, you said, is around 30 degrees Celsius, which is cooler than our body temperature, actually.

Dale: Yes, it's quite a bit cooler.

Dr. Biology: It's 36-37, right?

Dale: Yeah.

Dr. Biology: Wow. I want to talk more about the animals. I also want to talk about what Arno has been working on, and that's kind of the idea of the environment itself. And how do we regulate the environment so it's easier for us to keep our cool? Arno, can you tell us a little bit of ways that we can do this or some of the things you've been involved with?

Arno: Well, this thermoregulating system, I stumbled upon it about five years ago while looking through infrared cameras. And what I find interesting is to make the translation from what animals do and what people do. You look at environmental sustainable problems in the world, many of those are in one way related to the choices that people make, well basically thermoregulating.

Dr. Biology: Right, and on your website, World of Warmth, the images up there, let me just describe a few of them there. First of all, extremely colorful, and the range goes from a dark, deep blue all the way up to these incredibly bright reds and yellows. And it makes it pretty easy for you to understand what's going on with temperature because the reds and the yellows are the really hot areas, and we get down into the blues and the purples, that's the cool areas.

You use these when you're talking to people about thermoregulation, and when we talk about the animals we can see the different hot spots and the cool spots. Do you look at buildings?

Arno: Yeah, I look at everything. I'm some type of photographer, and a photographer needs light and needs contrast to create images. And I'm always looking for thermal contrast. So, when someone is having a cup of coffee, I see thermal contrast. When someone is having a cold Coke, I see contrast. When the sun shines on one side of a building, I see thermal contrast, or I always look at a surface and try to imagine what kind of temperature it might be in. I'm using more or less the same techniques photographers use with composition and contrast. But, the goal is always to make it as clear as possible for a broader audience.

Dr. Biology: Well, I have to say, a picture is worth a thousand words, and it seems like the thermographs are a picture full of hot and cold words.

Arno: And I try to use it as some kind of proof. It's not a goal in itself to make infrared images. I try to use it to prove these thermoregulation stories.

Dr. Biology: What does it take to take these thermographs? Go down to the local store and you can find an infrared camera? I mean, it used to be there was infrared film, but everything is digital now.

Arno: Yeah, well the technique itself is about 50 or 60 years old, so the technique itself is not new. It's originated from the military, you can imagine, night vision. In recent years, the technology has become cheaper and more available to carpenters or plumbers, for example, to find leaks in floors and find leaks in houses, or the technology the veterinarians use to find infections. So, in the last years or decades, it has become more available to the public.

Dr. Biology: How much does an infrared camera cost?

Arno: Well, they range from, I think $3000 to $50,000 $60,000. It is still expensive for a camera, but years ago they started at $30,000, $40,000, so they were not available for the plumber to find leaks. But, they are affordable and you have different qualities of course. It's about pixels, same as with normal cameras. With many pixels are still very expensive, but the cheaper ones, they produce a good image.

And we use many different cameras so once in awhile we borrow them or we rent them or we have cameras of our own. So, the collection of us, you will find many different images made by different cameras. It also depends on the topic you want to cover.

You can do the same in the wintertime. The aerial images were done in the wintertime as well to find insulation and leaks in roofs. So, you can use them both for in the winter as in the summer.

Dr. Biology: Oh, definitely, definitely. All right, well, let's talk a little bit more about our animals too here. So, we talked about the Gila monster and it's making choices, and I think, Arno, you've actually talked a little bit about choices that are made by humans. We'll talk a little bit about that, but let's talk about other methods that animals use to control temperature. You actually sent one to me, Arno, this morning about why flamingos stand on one leg.

Arno: When you take this thermoregulating point of view, you always wonder, does that have anything to do with thermoregulation. It must have been some thermoregulation tool or something. So, this standing on one leg by flamingos, it has been researched recently by scientists. And it seems to have a lot to do with thermoregulating. You can imagine, when you stand on one leg, the other one in between the feathers won't cool down as much as the one who's standing in the water.

Dr. Biology: Another example, Dale?

Dale: Another, actually one that came out recently also in the bird world, is a toucan.

Arno: Oh, I read it.

Dale: When you think of a toucan with its brightly colored, big beak, and people think, oh, that's to crush nuts and fruits; it's colorful for attracting mates. But, actually it's been shown that that large bill actually serves as a great heat radiator, actually releasing heat from the body and actually a way which these birds can cool themselves. And that's true whether you're talking about big elephant ears, or even dinosaurs like stegosaurus with these big spikes on their back were thought to be thermoregulators.

Dr. Biology: Right. So, in this case, they're figuring out mechanisms to release the temperature. Now, if we go to the world of polar bears, more recently they've been talking about the fur of polar bears, and it's actually not white.

Dale: Yeah. Polar bear fur is actually clear tubes and they actually have black skin to allow them to gain heat, and these clear tubes actually transmit this light into the skin where they can reabsorb it because black things get warmer. Being on the asphalt of the street versus the sidewalk, and if you're in Arizona you know in the summer you don't walk barefoot on the asphalt. But, yeah, so this white is just, that's what we're seeing, but really if you look at these hairs they're not white, they're clear and they're just fiber optics that actually bring light down. And if you also look at a polar bear, they also have very short ears. Ears aren't very important for them. They don't have to pick up far sounds. Sight is very important and staying warm is important.

So, you don't want these extremities to lose heat from, and you want to bring heat to the body. White's a good color for a polar bear. A black polar bear wouldn't eat too much out there as a seal could easily see this black polar bear coming, although it would be a nice way to warm up.

So, here's a compromise. This animal has a black skin, but you don't want to show that black skin so you have these fiber optic cables, these clear hairs that bring that light in to gain heat to the body. But, to something looking at it, it looks white. So, it's just a perfect compromise.

Dr. Biology: Right, and early fiber optics as you mentioned.

Arno: What might be interesting is a polar bear is really built to keep the warmth inside, but even a polar bear needs to release warmth when he has been running a lot. So, it's not only about keeping his warmth inside, but he also needs a tool or a trick or whatever to get rid of excessive heat.

Dr. Biology: So, what does the polar bear do to keep cool?

Arno: I think he's panting. Panting is one of the few things he can do. Because he's that well insulated, he doesn't have as much options. I think the main thing is panting. That is the reason why a polar bear can get a heart attack while running, because he gets overheated.

Dale: It is interesting that a lot of these polar animals, whether they're seals or polar bears, they have a greater risk almost of overheating than of freezing because they're so well adapted to dealing with it. They have insulation through blubber or hair, they have these short limbs and all these things. So, like a seal, if it comes out and basks to warm up, it can't do that for too long or else they can overheat, and they have to get back into the ocean to do that. So, it is interesting.

We tend to think about it because we are putting ourselves on the icecap in the North Pole or whatever, but these animals are well adapted to them. They have this insulations. They don't raise their metabolic rates to produce extra heat. They are so well insulated and they have all these adaptations for that temperature to be their comfort zone. They like it when it's below zero.

Arno: Right and part of the insulation again is fat.

Dr. Biology: It is fat and it is hair.

Dale: Well, this goes back to even humans. Another reason to keep thin is, if you have less fat it is going to be easier to keep you cool.

Arno: There is a great book about it. It is body heat and it is about anorexia and obese. Basically, it is a book about thermoregulation. It explains both problems from a point of view of internal regulating. It explains it a bit that people are more like tropical animals. They are built to get rid of excessive heat and are not really built or designed to keep warm in size. So, basically, we have to do more effort to keep warm when it is cold than to get rid of warm when it is warm.

Dr. Biology: So, how do people keep warm?

Dale: They can cuddle, and bring their arms in, huddling in. They have hair, especially if think about people, we have lost a lot of our hair over most of our bodies compared to most animals, but we do have a lot of hair on our head. That is because the brain you want to keep warm to have good function. If your brain is not functioning well you are not going too much of anything well. So, it is like with babies, you want to put hats on them all the time. Well, we have maintained the hair on our head to keep that heat in.

Dr. Biology: So, what is up goose bumps?

Dale: Goose bumps are basically a remnant of our past as being a furred animal. Basically, if you think of a dog when it gets cold, they will raise their hair and they will thicken their coat to fluff up. Birds do it too. They fluff up when they are cold. Well, the way you fluff up is you contract these little muscles in your skin that stand these hairs up. Well, we still have those little muscles in our skin, but we do not have the hair to stand up. So, when you get that contraction, that goose bump is actually this little muscle that is contracting, trying to get this hair to stand up. The hair is not in there so you get the bumps. Say you saw the dog when it raises its hair, he will also have these little bumps on him. So, a goose bump really doesn't do us any good. It is just a past remnant of fluffing ourselves up to keep warm.

Dr. Biology: Right, and I don't want to see a lot of dogs shaved out there just to find out they have goose bumps. [laughter]

Dr. Biology: We are going to take Dr. DeNardo's advice on that that it happens. That's some of the mechanisms of keeping warm. We have talked about animals, how they are keeping their cool. What do we do to keep cool? What in particular, we talked a little bit about them, but in general what are the major things that help us keep our cool?

Dale: Well, the primary thing we do is behavior. We go to a place where it is cooler. If there are trees you go under a tree. In Arizona, you don't see a lot of people out during the midday.

Dr. Biology: Arno's choices.

Dale: Yeah. Those are those choices. You make those choices, those decisions. Even though we are endotherms, we are producing our heat internally; we still could take advantage of external heat sources and cool environments also. So, we are making those choices. Another way we keep cool, the primary thing is we shiver if we are cold and, therefore, shivering, muscle contractions produce heat just like when we go running, and we sweat to cool off our bodies by producing that water, releasing it and evaporation from it. So, we use mainly shivering to warm our body and evaporative sweating for cooling off our body.

Dr. Biology: Right, and the shivering is as you said the muscles or contracting, which means they are doing work, and whenever work is done heat is generated.

Dale: Just like if you go running, you get very hot and not only do you get very hot and you feel hot, your skin turns very red and that's just your body trying to get rid of this excessive heat. When you went running you didn't do it to produce heat, but as a result of running you produce heat and you need to shed it. So, you bring this blood flow to your skin to release that heat.

Dr. Biology: We have our Gila monster that sounds more to me that part of its regulation is making choices, right? So, it chooses when it is really hot, if I can do it I will go out at night in the really hot times of that summer. If it is also hot, I can go deeper into the ground where it is cooler, burrow down further. Arno, do humans have choices?

Arno: Maybe too many choices. [laughter]

Arno: When we pick our holiday destination, 99 percent of the people who choose for a sunny location, we always talk about the weather. We all talk about having clothes, which is warm, which is cold. When we enter a room, we always say "Wow, it is warm here or nice and cold here." So, we are always thermoregulating every day. It really depends on the person's self which choices he makes - is he old, is he young, is he healthy, is he sick, does he like being pampered with all kinds of equipment, is he an outdoor person? Everyone does all the thermoregulating itself. Well, we know two of the same persons are using exactly the same thermoregulating toolbox. They are always making different choices.

Dr. Biology: Now some of our choices are whether we are going to be using things to cool us down or keep us warm that take a lot of energy, or things that work just as well that don't take a lot of energy. Can you give some examples in that?

Arno: Yeah, for example, I am obviously fascinated by the phenomenon of taking cold showers. About three to seven percent of the Dutch people take cold showers once in awhile. You have a choice. You can take a warm shower, a hot shower, or a cold shower. So, that is an obvious choice, and when many people make the same choices it might have serious effects on energy bills. You can put on the heat in your living room pretty high based on the person who is complaining the most, or you say "Well, I am lowering the room temperature or put on a sweater or something else. So, you can have many different choices, and they have huge impact on the energy bill. I think you can explain three quarters of your energy bill by thermoregulating choices.

Dr. Biology: Right.

Arno: That's why energy bills vary that much by household.

Dr. Biology: This is more than just talking about the physiology of keeping ourselves hot and cold. To give an example close to home here; we live where there is a lot of air conditioning, which takes a lot of energy, a ton of energy. But, you can actually raise the temperature and make it a little bit warmer in your house if you have fans moving air. So, Dale, why is it that I can go into a room and it has a fan blowing and it might be actually warmer than a room that's air conditioned to a lower temperature, but I feel just as comfortable?

Dale: Well, one of the things when your body is releasing heat, it's releasing it immediately to the air directly surrounding your body and the hairs on your arms and the tract that you get these little boundary layers that surround the body. Therefore, even though the room temperature may be 78 or 80 Fahrenheit, the immediate temperature the air just over your skin may be several degrees warmer because you are heating that air. Well, what the fan does is it blows that warm air that you've created off of your skin and it replaces it with other air that's slightly cooler and it continues in closed convection. So, it is conductive heatless in your environment, but the wind that's going is actually going is actually going to help move that air and keep up the gradient between you and that outside environment. So, it feels much more comfortable.

Dr. Biology: Arno, since we were talking about choices and some things that are going on in the animal world, you have this really wonderful project that's called "Trees for Grannies." Can you tell me a little bit about Trees for Grannies.

Arno: Yes, sure I'd love to. I started it about a half year ago, basically because there was a very famous campaign in the Netherlands called, "Trees for Cows," which ended last year. I was really sad that it ended so I had to find a way to continue this campaign. This Trees for Cows is a really clear campaign to plant more trees in meadows to provide shade for cows.

Dr. Biology: Do the cows use these trees? Did you find that?

Arno: Yes, they love them, because when it's a sunny day and you walk in a meadow with fences around, you can walk left or right, but you can't find any shade. A few trees, it really means a world of difference for those cows. Coming back to choices, three or four trees in a meadow means very important extra choice for these cows. There was also a big heat stroke in 2005 in the Netherlands, which also affected health care locations, senior homes.

It was horrible, like thousands of people died early basically because of the heat. I tried to translate this, *Trees for Cows,* into a campaign suited for the health care area. To explain them a little bit about thermoregulation and put the finger on green. Use more trees; use more shrubs around buildings to be able to cool it down.

To give also the older people a choice like the cows. When it's hot you can stay inside. We can also look for a cool tree. I have feedback from several governments that they have planted extra trees based on this story.

Dr. Biology: Well, with Ask a Biologist, I always ask three questions of all my guests and you guys I'm not letting you off the hook. I'm going to start with Dale. When did you first know you wanted to be a scientist or biologist?

Dale: Early on as I was just growing up as a teenager, I was thrilled by a question. It was always about a question. If I got an answer, it was always what's the next question or the next two questions. I didn't know what the careers were to deal with that, but I did know I liked asking questions and I liked trying to answer them. Then as I went through school and I realized as a biologist, I could put that love of animals together and my just natural tendency to want to answer questions together.

Dr. Biology: This would be from a really early age.

Dale: It's a very early age. I was one of those fortunate people that knew early on what I wanted to do and I was in an environment and had the necessary skill sets to actually achieve that.

Dr. Biology: Arno, you're really hooked on doing these actually really artistic things and you do a lot in the world of engineering. When did you know you wanted to do this?

Arno: Well, I stumbled upon this topic of thermoregulation only about five years ago when I started projects using infrared cameras. In that case not a real scientist. I just found this topic of thermoregulating. Since then I've been reading and learn as much as possible about it because I finally found what I was looking for I think.

Dr. Biology: What did you like to do in school when you were growing up? What was your favorite subject?

Arno: More of the biology type of subjects. I love to look around. I'm more like an observer, look around.

Dr. Biology: Which is science. Number one thing.

Arno: Yes, basically.

Dr. Biology: If you don't observe the world around you, you're going to have a really hard time being a scientist. Well, what if I took it all away from you? What if I said you couldn't be a horticultural engineer, someone interested in environment in the way you are and you can't do your wonderfully cool images? What would you do, what would you be?

Arno: I got a bunch of friends I have around street theater. Company is a big one. We do a lot of street theater acts in the Netherlands. Musical, what do you call it? Children's orchestra like we give away all kinds of instruments and we make a really lot of noise. Try to make it some kind of song.

Dr. Biology: [laughs]

Arno: That's what I would probably do if I wasn't involved in this thermoregulating thing. I would do it probably more than I'm doing it right now.

Dr. Biology: A street performer. I like it. [laughs] All right. Well, Dale, I'm going to take everything away from you. I don't know if I mentioned that you're also the veterinarian here at ASU. I'm taking that away, you really got to stretch.

What are you going to be, what are you going to do?

Dale: That's a tough call. I don't have an artistic side. I enjoy the arts. Probably, I'd switch over to something like engineering, even if it's mechanical engineering. I'm always amazed when you pick up a simple instrument. I was just using a simple pair of wire strippers recently and I just looked at these things and I just said, "To come up with that solution to a problem." Again, you get to challenge your mind, you get to think.

Dr. Biology: You'd be an engineer. All right, what advice do you have for a young person? What's your advice?

Dale: First keep your eyes open. See what's around you, don't have preconceived opinions. Don't do what mom and dad want you to do. Don't do what you want to do because you wanted to do it since you were five. Always have an open mind. Always be seeing what is out there. The second thing is learn more about it. Go out there and figure out what does it really mean to do that. Get involved. Work for people who do that or even volunteer for people that do that. Get experience doing it.

It's not going to come to you for free. It's not going to come. You definitely have to put energy and effort into it. If you have the commitment and the drive, you'll be able to do what you want to do.

Dr. Biology: Arno, what's your advice?

Arno: I agree. Put more energy in learning about biology. I've been working on this thermoregulating for five years now and I think I understand maybe five, six percent of all the stories out there.

Dr. Biology: [laughs]

Arno: There's so much to learn out there about biology. If we don't, well, I think we're losing site of very interesting stories. When you have the chance, learn about the stories.

Dr. Biology: Even though I have a lot more questions, it seems to be time to say goodbye to our guests. I want to thank you Dale DeNardo for being on Ask a Biologist.

Dale: Glad to be here.

Dr. Biology: And Arno Vlooswijk. I can't thank you enough for being willing to experiment with us on our new Skype set up in the Grassroots Studio. You sound like you're right here with us even though you're on the other side of the world in the Netherlands.

Arno: You're welcome.

Dr. Biology: You've been listening to Ask a Biologist and my guests have been biologist Dale DeNardo from the ASU School of Life Sciences and from the other side of the world engineer, Arno Vlooswijk. If you haven't already made a note about the World of Warmth website the address is worldofwarmth.com. There is a collection of some amazing images you need to check out.

Also be looking for a companion article on Ask a Biologist on thermoregulation, because I'm really counting on Arno sharing some of these cool images with us. Is that a deal?

Arno: Yes, it's a deal.

Dr. Biology: OK, the Ask a Biologist podcast is produced on the campus of Arizona State University and is recorded in the Grassroots Studio housed in the School of Life Sciences, which is a unit of the College of Liberal Arts and Sciences. Remember, even though our program is not broadcast live you can still send us your questions about biology using our companion website. The address is askabiologist.asu.edu or you can just Google the words, "Ask a Biologist."

I'm Dr. Biology.

Transcription by CastingWords