Rhiannon Macrae: Tell us a little bit about the battle of the sexes, or at least battle of the sex chromosomes. Can you give us a brief history of where the X and Y chromosomes came from?

Dr. Page: Over the last 200–300 million years, not long after we parted company with the ancestors of birds, an ordinary pair of autosomes began to become today’s X and Y chromosomes. Now, the X and the Y chromosomes are very different. The X held on to most of the genes that were on that ancestral autosome, but the Y lost most of them. The human Y chromosome today hangs on to about 17 of the almost 700 genes that were on that ancestral autosome. It’s been speculated that the Y chromosome is going to disappear altogether in maybe a few million years’ time, but if we compare the human Y with the Y chromosomes of other primates, it becomes quite clear that the gene content of the Y chromosome has stabilized. It lost a lot of genes millions of years ago, but it’s flying at a pretty steady, if low, altitude right now.

Rhiannon Macrae: You’ve got some recent results that suggest that there’s a lot more going on with the Y than just what people traditionally think of as its role.

Dr. Page: We’ve been learning a lot about the Y chromosome, not only by looking at the human Y, but also by looking at the Y chromosomes of mammalian relatives like the mouse. The mouse Y chromosome is actually four times the size of the human Y and it has an outrageous amplification of a small number of genes, so outrageous that this small number of genes and the DNA in which they’re embedded have come to comprise 95% of the mouse Y chromosome. The crazy thing is that the genes that are embedded in this 95% were not on the ancestral autosome that gave rise to the Y. We didn’t have any inkling why this was until we looked at the mouse X chromosome. We found that there were similar genes—not identical, but related—also amplified on the X chromosome in the mouse that were not from the ancestral autosome. These had to have come from elsewhere. We now think that these amplified genes on the Y and on the X are evidence of what we suspect is a pitched battle between the X and Y chromosomes to be transmitted to the next generation. We conventionally think it’s 50/50 whether it’s a male or a female offspring in the next generation. It’s female if the sperm that fertilizes the egg carries an X chromosome, and it’s male if the sperm carries a Y chromosome. If you’re a Y or an X, you might get some selfish ideas and say, “Next generation, I’d like to win more than 50% of the time at the expense of the other.” This is a meiotic drive, or a segregation distortion. It’s selfish chromosome behavior. We think these genes that are amplified on the Y or on the X have become combatants in this battle between the sex chromosomes. We think they’ve been imported into the Y, but that they’ve been imported independently into the X and they’re fighting on behalf of their host chromosomes against each other.

Rhiannon Macrae: Do you have any idea what these genes do?

Dr. Page: These are protein-coding genes. It’s a very small number of proteins that are encoded by these genes, but they’re present in literally hundreds of copies on the Y, and at least dozens of copies on the X. By comparison to other known proteins encoded by the genome, we think that the proteins they encode are involved in the processes of actually transmitting the chromosomes from one generation to the next. We think these proteins are physically involved in binding to chromosomes and helping transmit them. Another possibility would be that these are messed-up versions, things that could potentially poison the rival chromosomes.

We’ve recently seen something similar in the bull X and Y chromosomes. There’s an outrageous amplification on the Y and some amplification on the X of very similar but nonidentical proteins. We’re now looking back at discoveries we made 15 years ago through new eyes and see that there is an amplified gene family on the human X, and a related amplified gene family on the
human Y that look very much like they could be taking on antagonistic roles and might be serving on behalf of their host chromosomes in a battle for transmission to the next generation.

**Rhiannon Macrae:** When you say “bull,” I think of breeding. Humans have bred cattle for many years. How do you know that you’re seeing the ancestral state versus what humans have shaped?

**Dr. Page:** Selective breeding of cattle might have somehow enhanced certain traits, but there are a lot of other living species related to the domesticated cattle, *Bos taurus*: water buffalo, bison, the gaur. Together with some collaborators, we studied samples from all of these existing species and they all have these mercenary genes embedded on their X and Y chromosomes. This phenomenon has likely been in place in cattle for at least 17 million years, so it’s not something that is due to human intervention.

**Rhiannon Macrae:** We’re celebrating the 150th anniversary of Gregor Mendel’s laws. Do you remember learning about the laws of inheritance or doing a Punnett square for the first time?

**Dr. Page:** It was high school where I had my first biology class. Hardy–Weinberg principle, all that stuff, even beyond Mendel. Of course, what I’m talking about now with this battle between the sexes is basically about the X and the Y trying to bend the rules of Mendel. Basically, when our sex chromosomes evolved, it meant that we were “Mendelizing” the question of becoming a male or a female. You’re making it 50/50. This is really talking about all these species, including ourselves, disrespecting the laws of Mendel and trying to bend them in selfish ways.