A Devil Worth Saving

New Mexico Supercomputing Project

Final Report

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Executive Summary

This project is about the Tasmanian Devil, an endangered species ([14]) found only on the island of Tasmania ([10]). Australia in 2006 declared devils 'vulnerable to extinction' ([7]). Our goal in this project is to use Starlogo TNG to model the Tasmanian Devil, and the impact from the Devil Facial Tumor Disease (DFTD), which is quickly killing the devils. There were several challenges that we faced including; finding time to work on this project, researching the Tasmanian Devil, properly referencing the data we found, learning the basics of Starlogo TNG, and learning how model a problem.

We are using Starlogo TNG to model the population of the healthy and sick devils. With our program we can model a decade in a matter of minutes. This will allow us to simulate a number of strategies to get rid of DFTD.

We learned a lot about Devil Facial Tumor Disease and we are concerned the devils are heading for extinction. We were able to make the computer model "balanced" before introducing DFTD. When infected devils were introduced to the program landscape the population of devils went to zero. We think this will happen eventually in real life, but we can't prove that, yet.

What is a devil?

The Tasmanian Devil is the largest carnivorous marsupial in the world ([11]) about the size of a small dog. They are scavengers and cannibals ([8]) and the most important meat eater on the island of Tasmania, which is located South-East of Australia ([8]). The island of Tasmania was discovered by the

Dutch explorer Abel Tasman in 1642 ([15]). The devils help maintain balance in the Tasmanian ecosystem ([2]). Scientists are concerned that with devil loss, animals such as big cats and foxes will upset the balance of other animals on the island and cause extinction of other species ([13]). The name Tasmanian Devil was given by early European settlers because of the ferocious screams and growls made by the animal ([12, 9]). The only predator the devil has is a Red Fox and the Red Fox was illegally brought to Tasmania ([4]).

Devil Facial Tumor Disease (DFTD)

DFTD is a transmissible cancer, one of only 3 transmissible cancers currently known in nature, with the other two being Human Papillomavirus and Canine Transmissible Venereal Tumor ([6, 13]). "The suspected means of transmission is highly unusual. Scientists believe that when one animal attacks another, it leaves cancerous cells behind in the bite." ([6]) The DFTD spreads throughout the devils body, concentrating on their face and head ([10]). Most devils infected will die within 6 months of getting DFTD ([13]). One problem is that the devils have low genetic diversity, so the cancer spreads easily from one devil to the next, and scientists have shown that the cancers all are similar genetically and believe the cancer traces back to one devil ([13]). Also, due to the DFTD, the adult population appears to be dying by half of the population each year ([14]), which is a big problem for their survival since fewer will have babies each year, or live long enough to raise a litter of babies to independence ([14]).

The disease first started in the northeastern part of Tasmania ([2, 13]), but has spread throughout the country in all areas except for the northwestern corner ([13]) where the devils seem to be genetically different from the ones on the rest of the island. Until the appearance of DFTD in 1996 ([13]), the devil population was estimated to be 150,000 ([14]). In 2008 scientists estimated that the devils numbers had decreased by 60% ([14]). They estimate devil density to be 1 devil/square km with a range of 7 km/day ([5]). We tried to use these numbers in our program but we still need to get all the information correct in our modeling. DFTD is killing off the devils quickly but other things threaten them including: predators, increasing human population, being killed on roads while scavenging for or eating roadkill, and habitat loss ([2]).

Habitat

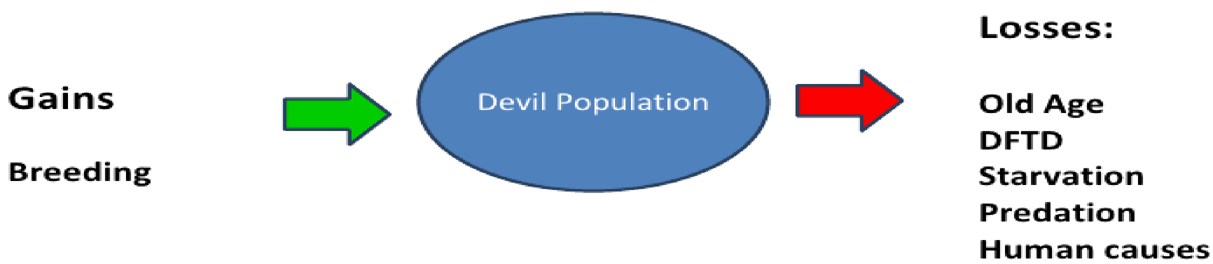
Tasmanian devils range over the entire island of Tasmania. Devils prefer to live in forests and coastal woodlands, where they require a large territory with a range that covers 10-20 km squared. Frequently their territories overlap ([1]). Devils move up to a maximum of seven kilometers on successive nights ([3]). The devil shows a preference for habitats with an open understory or routes through vegetation and they live in wombat burrows or natural caves ([4]).

Food and Reproduction

Tasmanian Devils are dying rapidly because of DFTD. Many scientists that are studying them think that the devils will become extinct if a cure to DFTD can not be found ([7]). Devils are carnivores and will eat almost any meat ([8]) such as: birds, fish, insects, small reptiles, wallabies, echidnas, platypus, fruit, seeds, eggs, and garbage ([8]). One of their favorite foods is a wombat ([10]). They are both a predator and scavenger – eating live and dead animals ([8]). Scavenging is important because they clean up dead animal carcasses. Sometimes Tasmanian Devils are even cannibals ([14], [2]). The average life span of a healthy Devil in the wild is 5 to 8 years. The devils will have up to 40 babies of which 0 to 4 babies survive ([10]) due to the mothers only having four nipples. A devil baby (or joey, pup, or imp) will leave its mother at nine months ([4], [8]). The first year on their own kills up to 60% of the young devils ([10]). Traditionally devils would start reproducing at 2 years of age, but since the disease has spread so far, they are now breeding at 1 year of age ([13]).

Computer modeling

We think computer modeling is important. For example it is cheaper to model a problem on a computer than actually trying out a bunch of ideas in real life and not knowing if they are going to work. Computer modeling allows for rapid assessment of solutions for specific problems. We used StarLogo TNG to model the healthy and sick Tasmanian Devil population. Population is gained through breeding and is lost by dying of old age, DFTD, starvation, predation, and human causes (e.g., roadkill and poaching). To steady the population you need to even out the gains and losses which is hard to do within our computer model. Nature keeps a steady population with a complex balance of animals, plants and humans. We used variable reproduction rates and differences in energy gain or loss to balance the population in the program. We used collisions to represent the transmission of the DFTD. We had to adjust the infectivity rate (how many start sick) and adjust the sick rate (how well a devil can transmit the disease).



Change in the Number of Devils = Gains - Losses

A steady state population requires that:
Gains = Losses

We modeled healthy males and females, sick males and females, foxes as predators and mortality by cars. We used collisions of healthy and sick to cause healthy ones to become sick, collisions of males and females to cause reproduction, collisions of devils and food to cause devils to gain energy. Loss of energy shortened the typical lifespan for sick devils.

Results

We wrote a program that contained as agents, male devils, female devils, foxes (predator), and a car (human effects). We had as variables things we could control from the interface: starting numbers of female /male devils, foxes, percentage that were infected, the transmission probability, death rate by car, and probability that a fox will be successful.

We were successful in writing a program that ran on our computers. Shown in Figure 1 is data taken from our program run without infected devils, but with a 5% roadkill rate and a 5% predator rate. We started with 30 female and 30 male devils, and 1 fox. There is only one car in our program. As shown in Figure 1, the population of male and female devils would fluctuate, with dips to below 10 males or female devils. However, the population would recover. The data was taken through 10000 cycles, which is 25 years in our program. (1 cycle = 1 day / 400 cycles = 1 year). This result showed that we could simulate a devil population that was relatively stable over a long period of time.

Figure 1: Data from our program run without the DFTD disease.   We stopped the data after 10000 cycles, which is 25 years in our program.   (1 cycle = 1 day/ 400 cycles per year) Setup: Started with 30 female and male devils each with no sick, 5% predation and 5% roadkill rates.

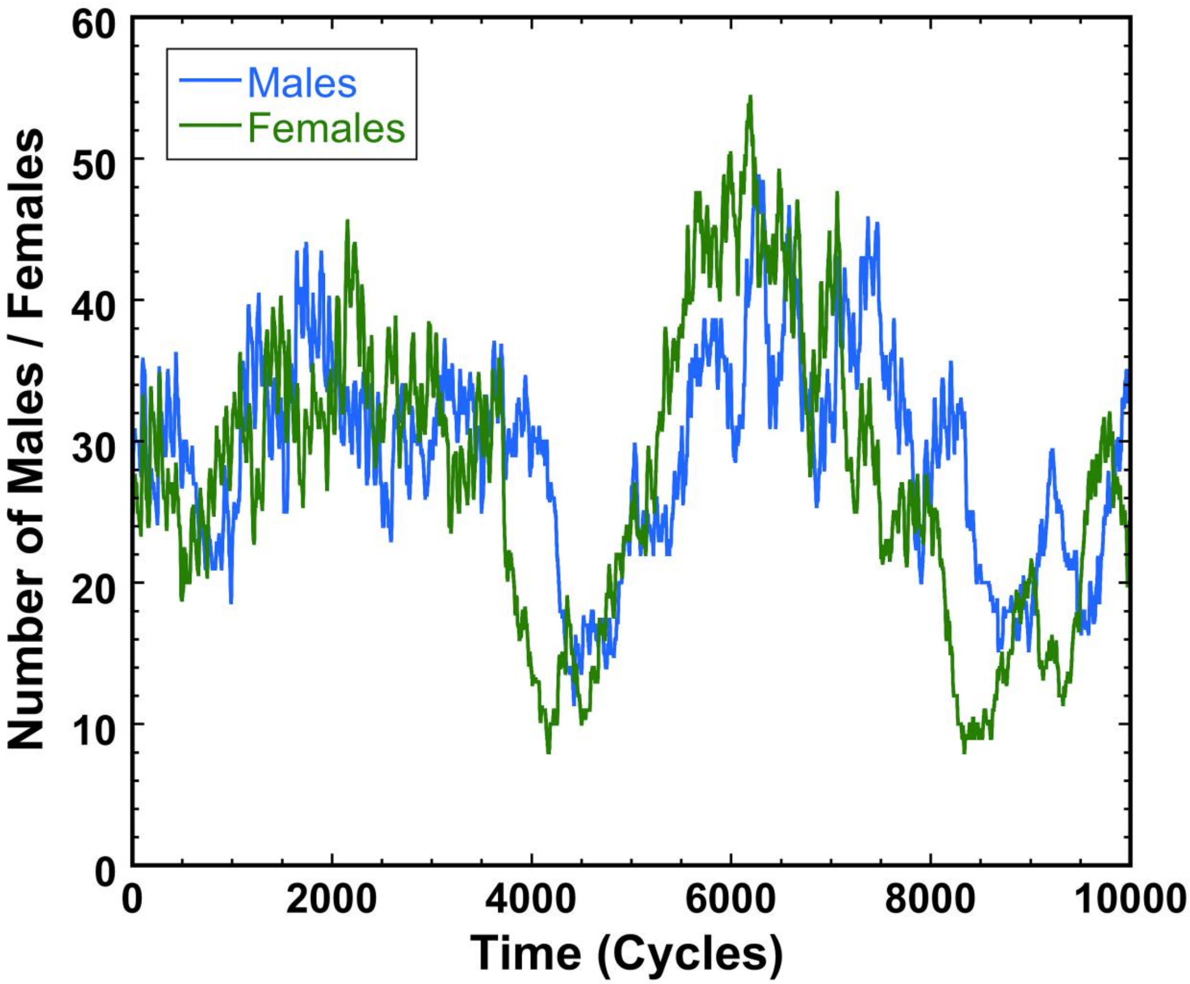


Figure 2: This is what happened when the roadkill was too high. The population lived for about 1 1/2 years. We averaged 3 runs in this graph. Setup: Started with 30 female and male devils each with no sick, 5% predation and 33% roadkill rates.

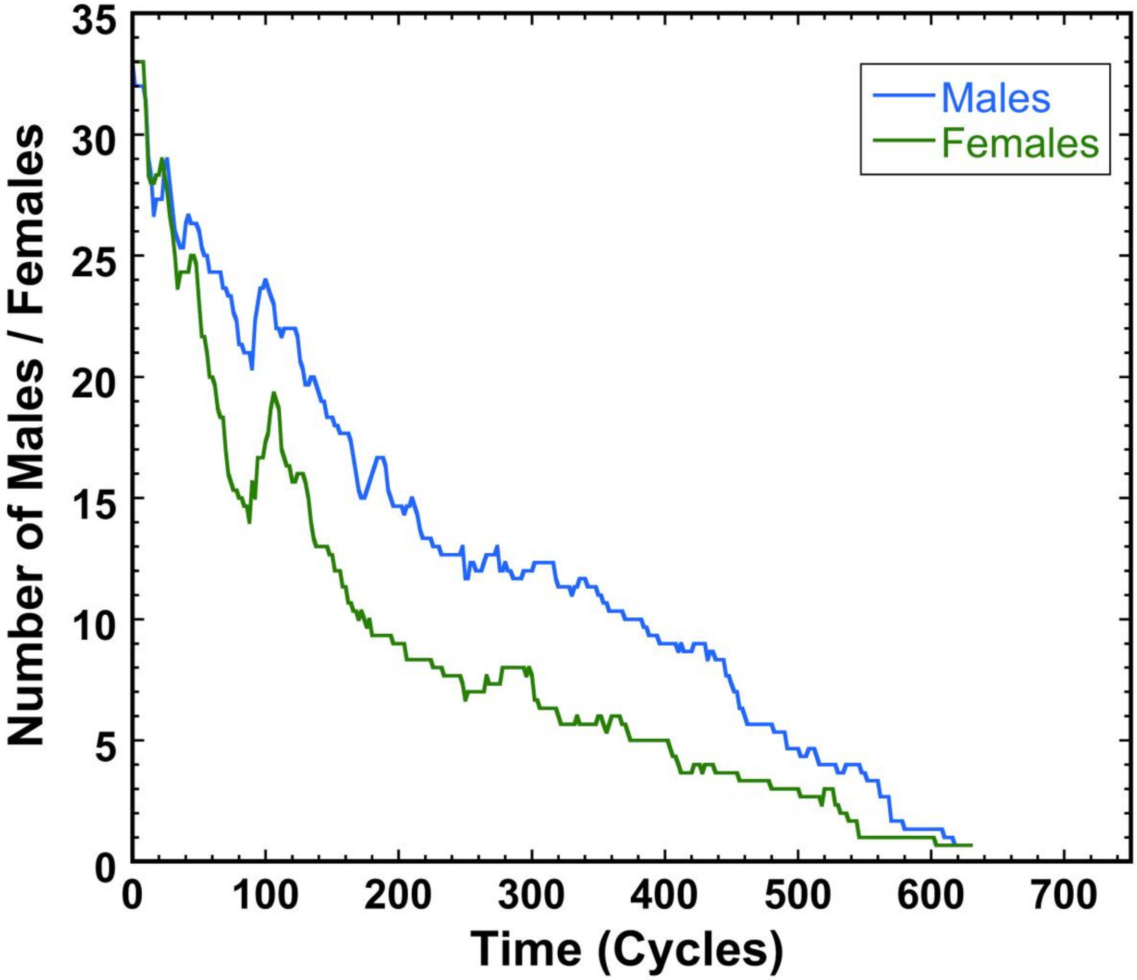


Figure 3: This is what happened when the predation was high; they lived for about 2 years. We averaged 3 runs in this graph. Setup: Started with 30 female and male devils each with no sick, 33% predation and 5% roadkill rates.

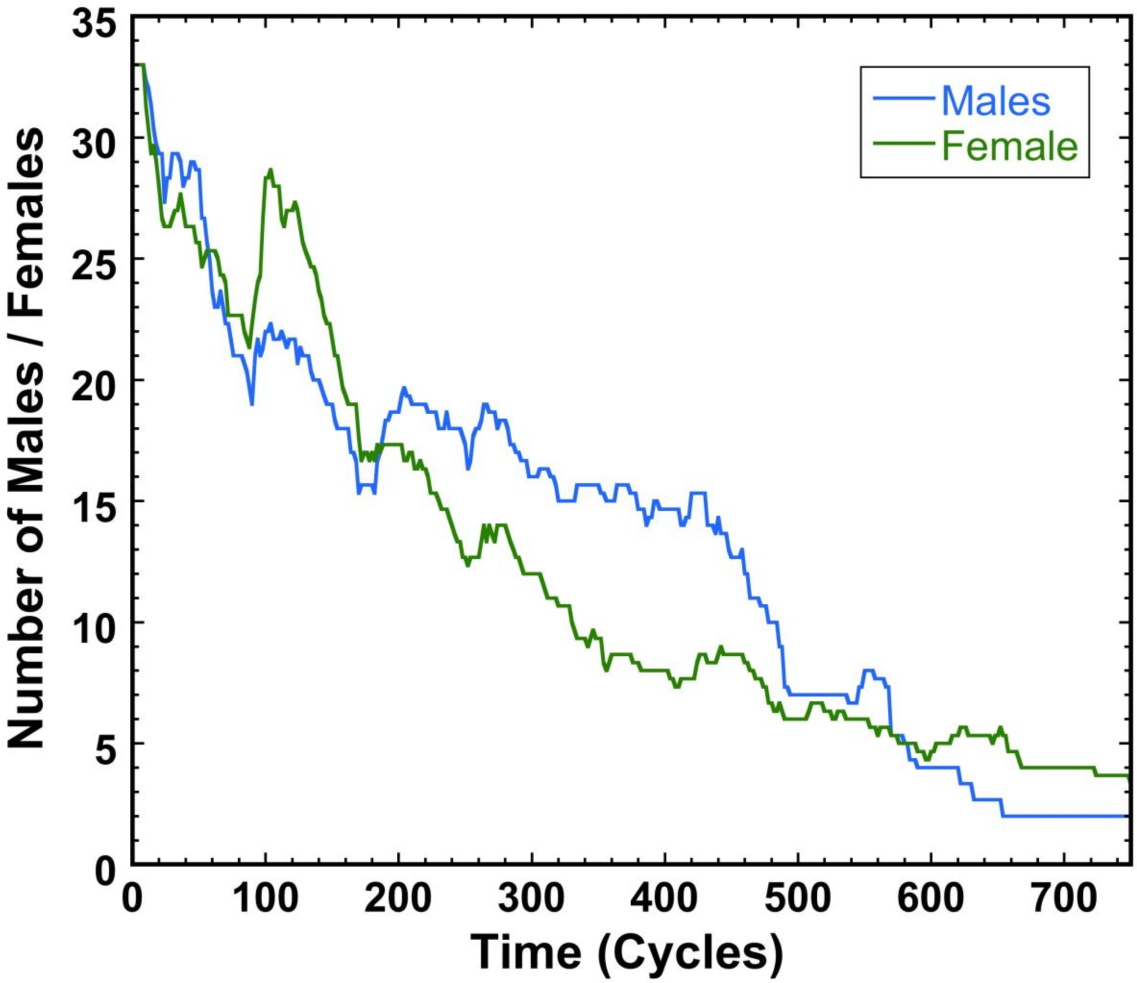
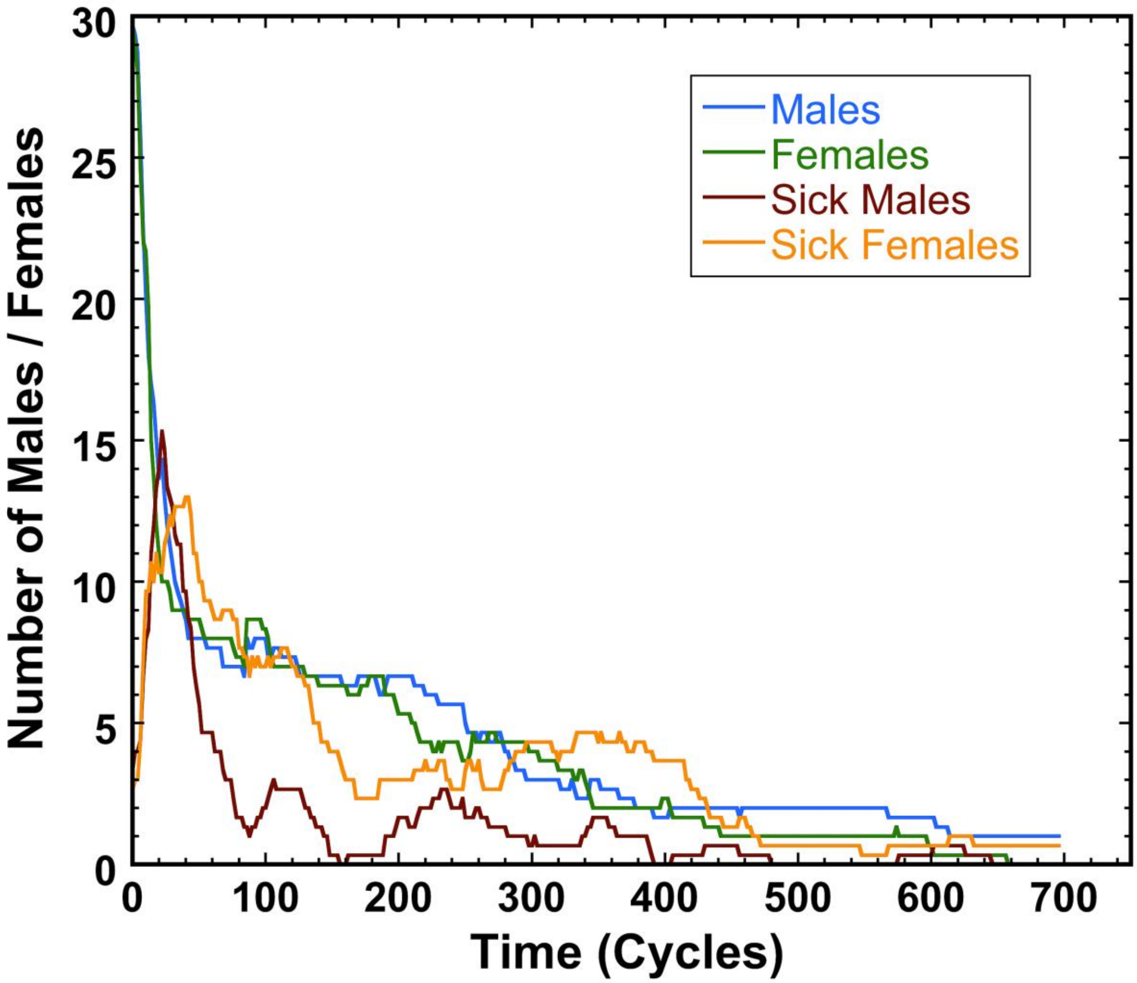


Figure 4: Some are sick and the disease kills off the Tasmanian devils. We ran the program 3 times and averaged the data. Setup: Started with 30 female and male devils each with 10% sick, a sick transmission rate of 10%, 5% predation, and 5% roadkill rates.



While we could get a stable population with modest amounts of roadkill (human interaction) and predation, high amount of either would kill off the population. Assuming our stable population mimics the real world, this suggests that introduction of new devils into the wild (repopulation) will need to take into account factors such as human interactions and predators for the new populations to succeed.

When we added sick devils to the population, we found that the entire population became sick and died shortly thereafter. We know from our literature searches that the population has been sick for many years, with nearly 60% sick after 10 years of the disease. So, there are some issues with our program in modeling the transmission of sickness within the population. Things we are having trouble with, due to a lack of hard facts, are the incubation period for the disease and the probability of transmission during an encounter. We tried to add these variables to the programming through transmission rate and percentage sick to see how the population would respond. We found in the limited number of trials we were able to run that we could not have a steady state population of devils with some sick that lasted more than 2 years. This will be an area we need to find more data for, if it exists, in the next year.

Conclusion

We learned a lot about Devil Facial Tumor Disease and we are concerned the Tasmanian Devils are heading for extinction which will cause big problems in their ecosystem and other Tasmanian animals may become extinct due to other predators. We were able to make the program balanced so that in our program the devils live “forever” when there are no sick and a 5% chance of roadkill and a 5% chance of fox predation. It became more challenging to balance the program when we added real numbers from our research (e.g., devils can move 7 km on successful nights). We successfully made a stable population of devils before we introduced DFTD. When infected devils were introduced to the landscape the population of devils went to zero. We think this will happen eventually in real life, but we can’t prove that, yet.

Recommendation

Our team plans to continue this project next year. There are many details we could model that we ran out of time to model this year. More research is being done on this problem as we write our final report. We will have more papers and more up to date information to review next year.

Acknowledgments

Thank you to the staff at Aspen Elementary School for supporting our team effort, to our mentors for their help, to the volunteers who coordinate the New Mexico Supercomputing Challenge project.

References

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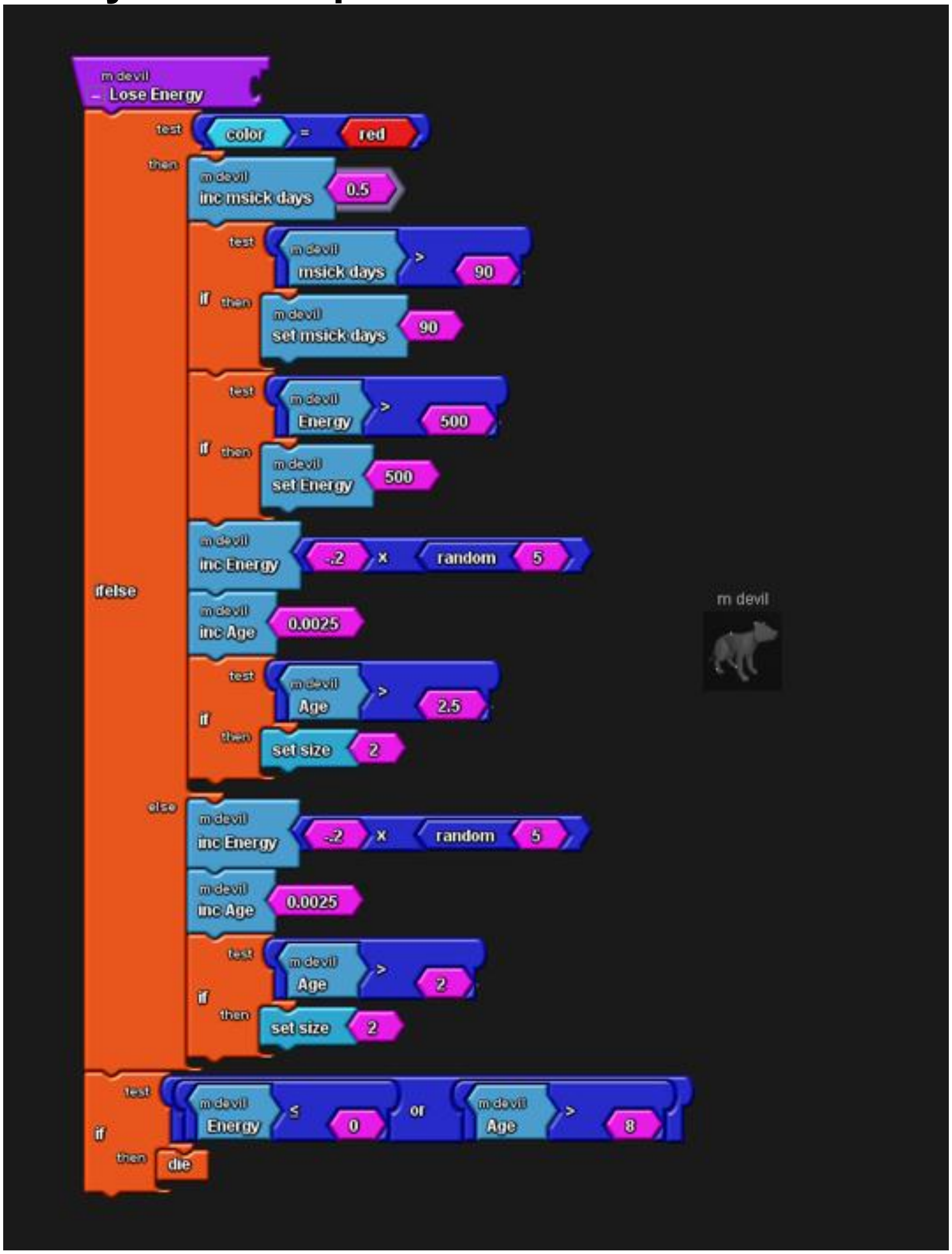
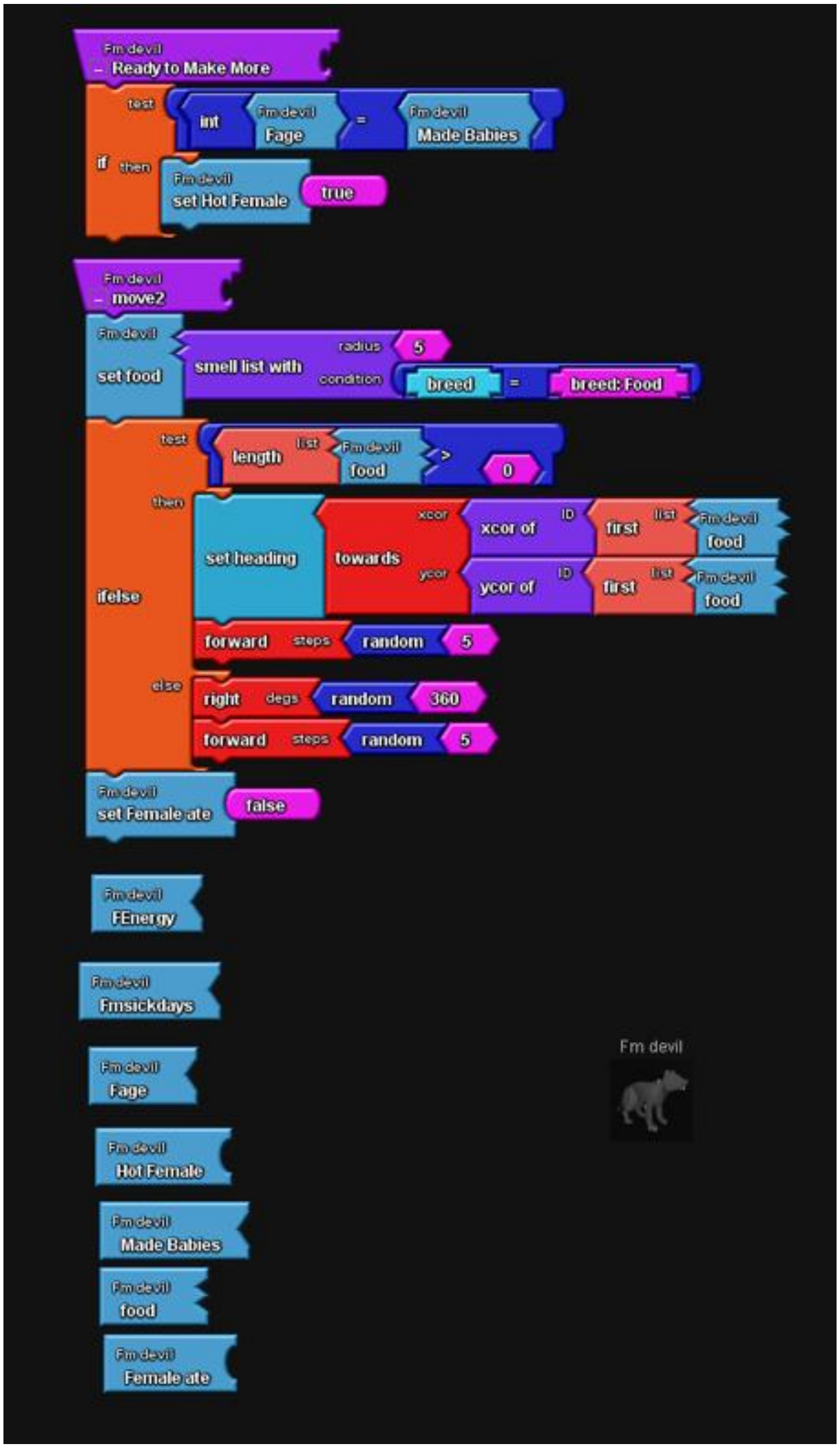
15. "Tasmania." *Wikipedia*. Wikimedia Foundation, 04 Jan. 2012. Web. 01 Apr. 2012. <http://en.wikipedia.org/wiki/Tasmania>.

This year's computer code

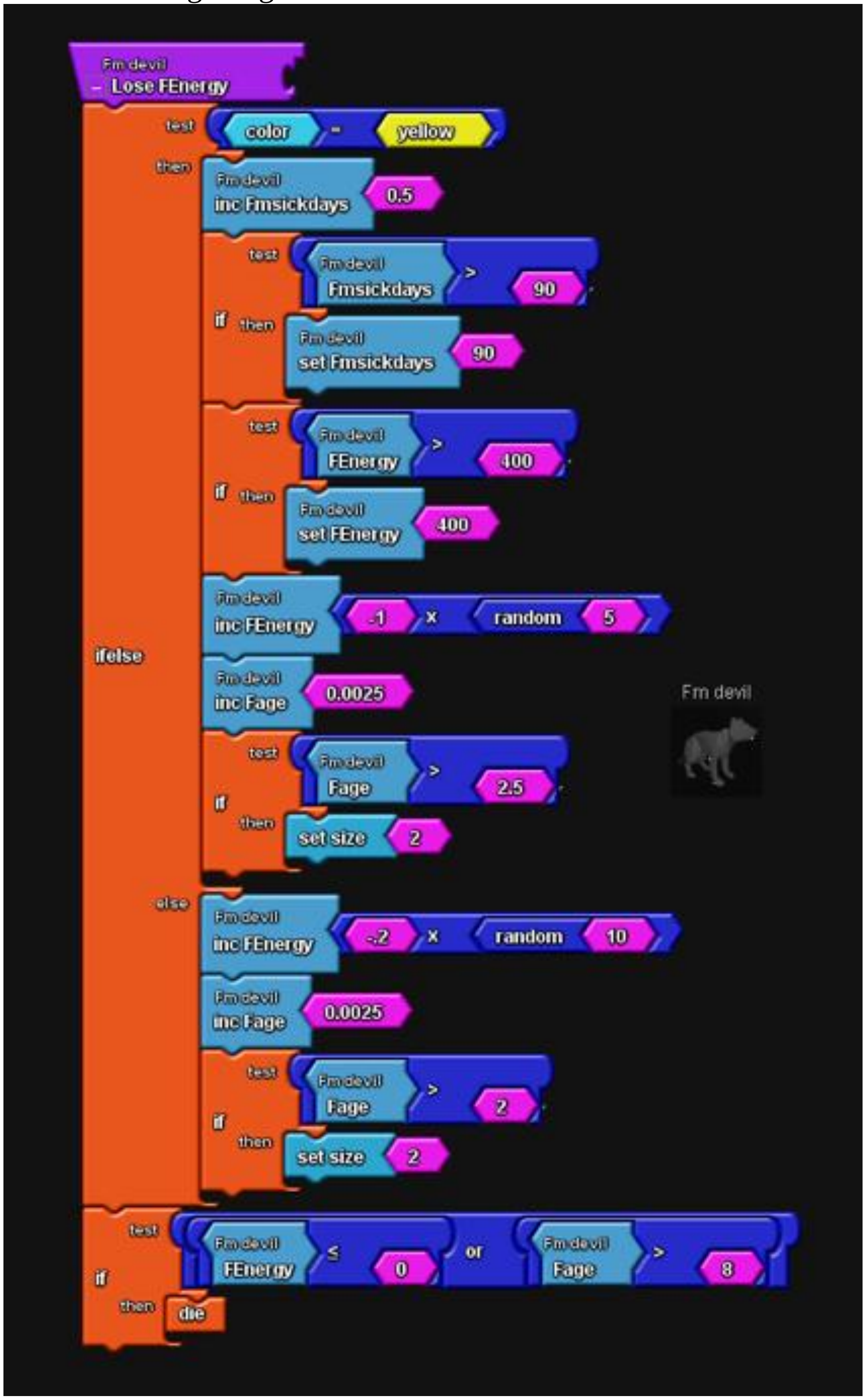


Males sick loosing energy

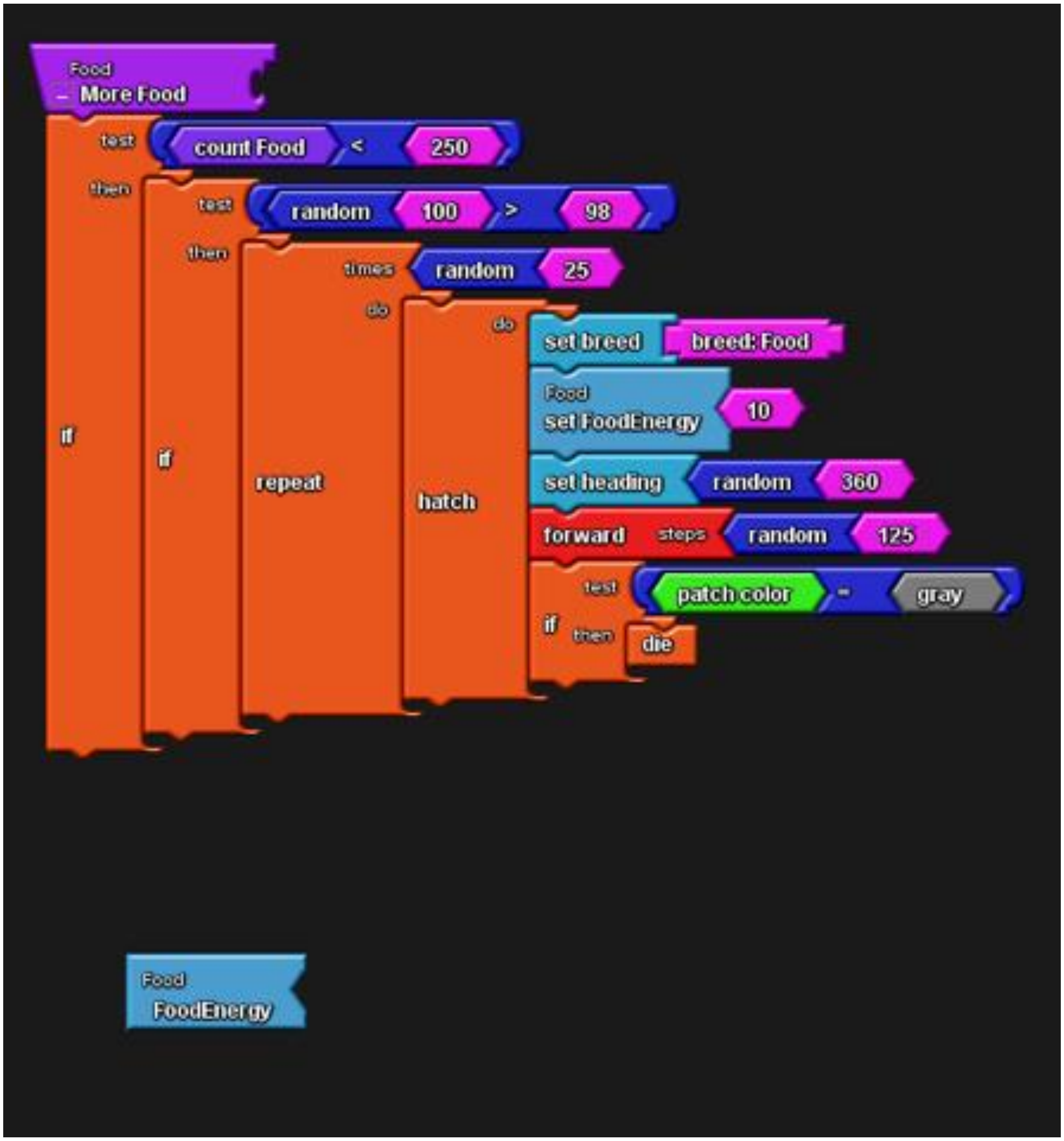


Females getting ready to make more

Female devils getting sick:

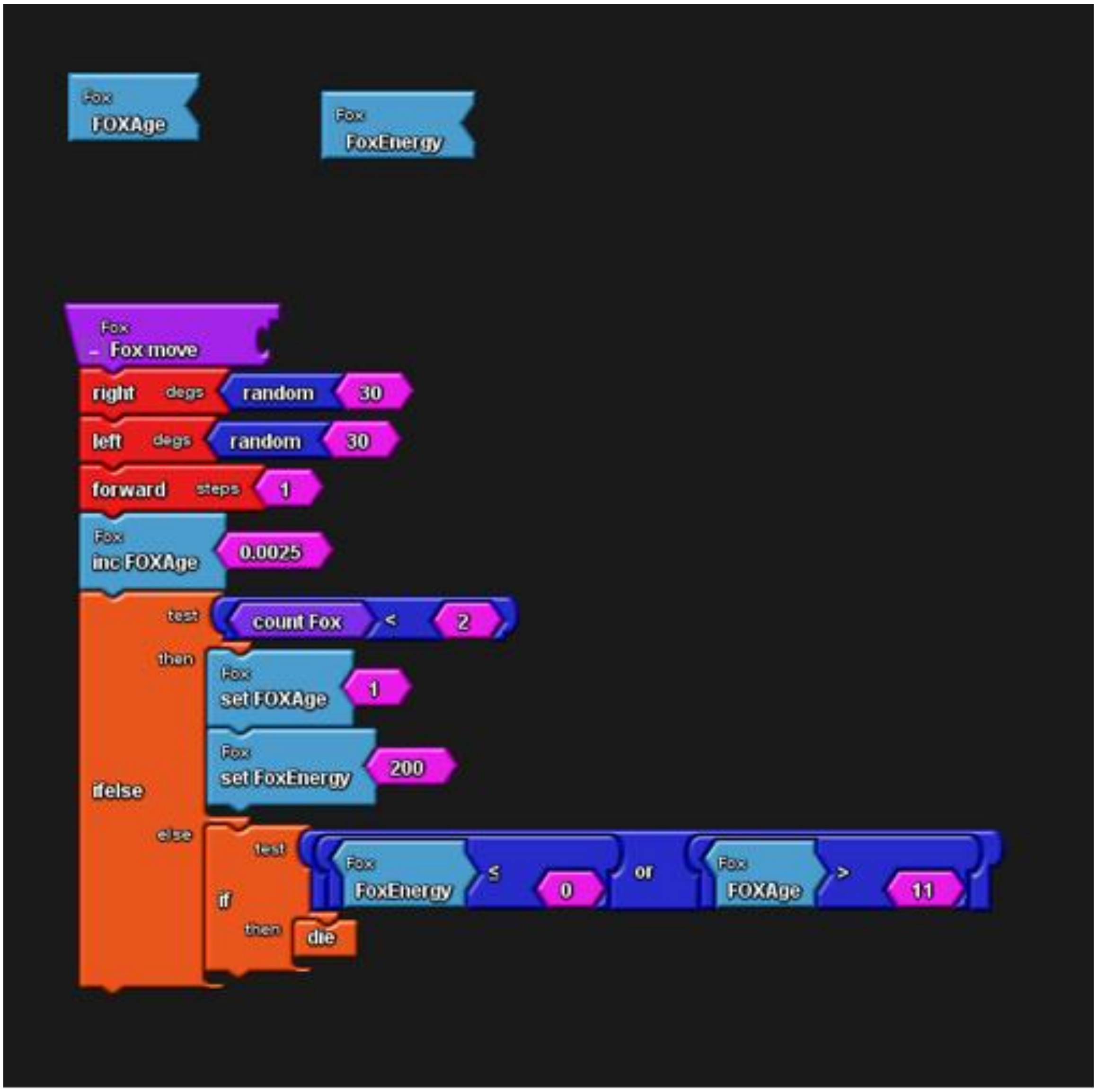


Food:

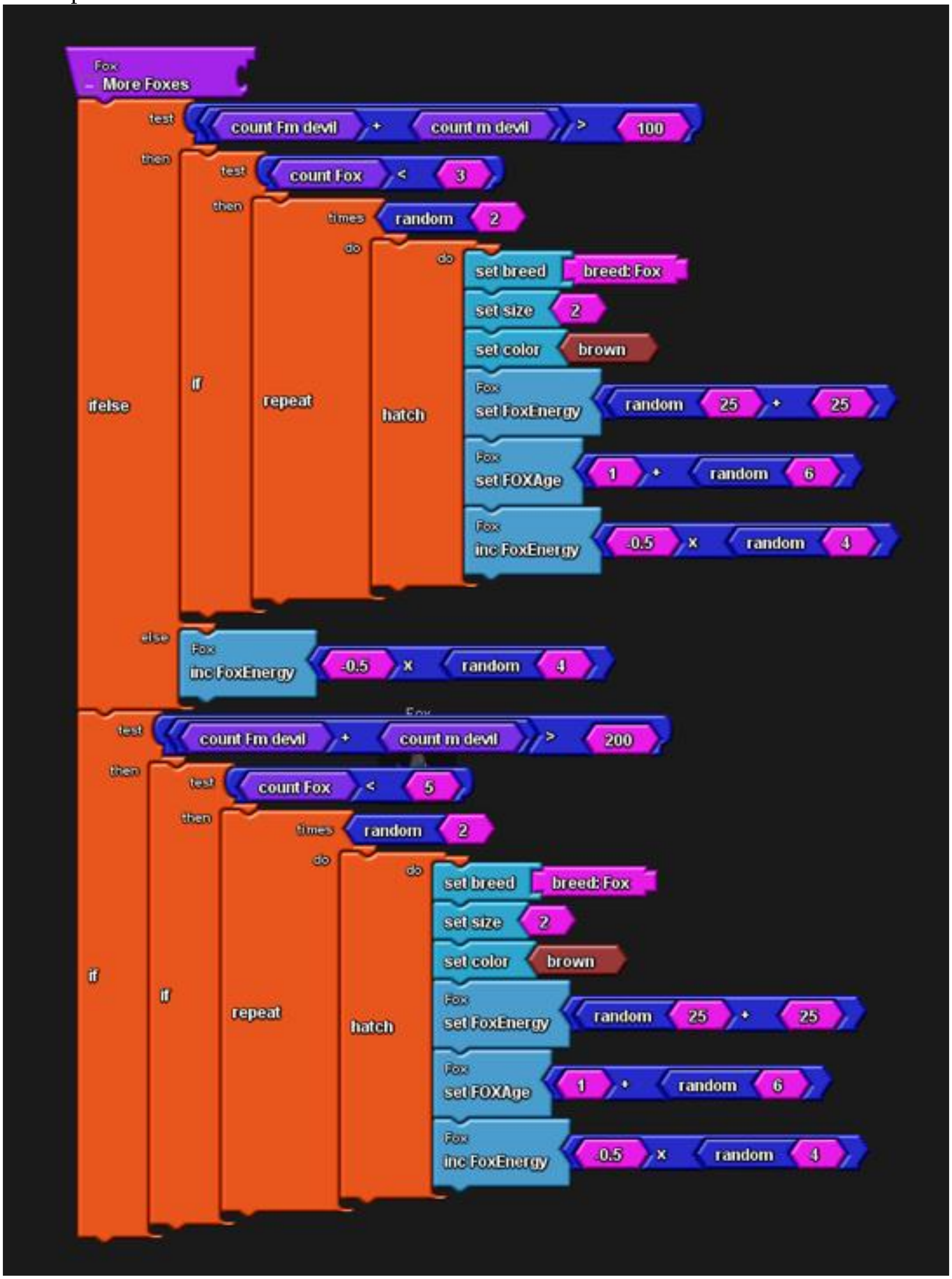

Food
More Food
test
count Food
<
250
then
test
random
100
>
98
then
times
random
25
do
do
set breed
breed: Food
Food
set FoodEnergy
10
set heading
random
360
forward
steps
random
125
test
patch color
=
gray
if
then
die
if
if
repeat
hatch
Food
FoodEnergy

Car movement:

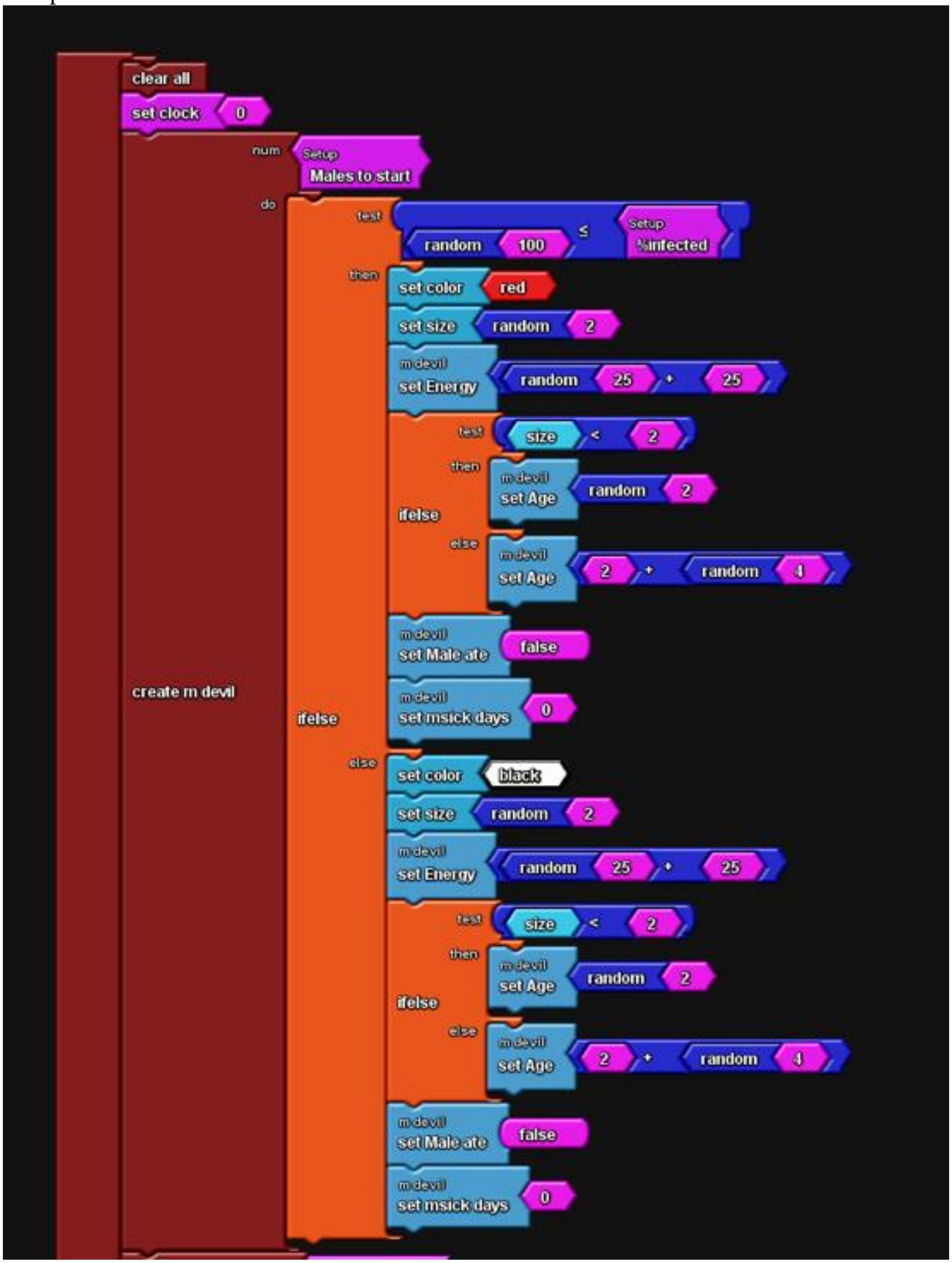
Fox
movement:



Fox reproduction:



Setup:


clear all
set clock
0
num
Setup
Males to start
do
test
random
100
≤
Setup
%infected
then
set color
red
set size
random
2
m devil
set Energy
random
25
+
25
test
size
<
2
then
m devil
set Age
random
2
ifelse
else
m devil
set Age
2
+
random
4
m devil
set Male ate
false
create m devil
ifelse
m devil
set msick days
0
else
set color
black
set size
random
2
m devil
set Energy
random
25
+
25
test
size
<
2
then
m devil
set Age
random
2
ifelse
else
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set Age
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+
random
4
m devil
set Male ate
false
m devil
set msick days
0

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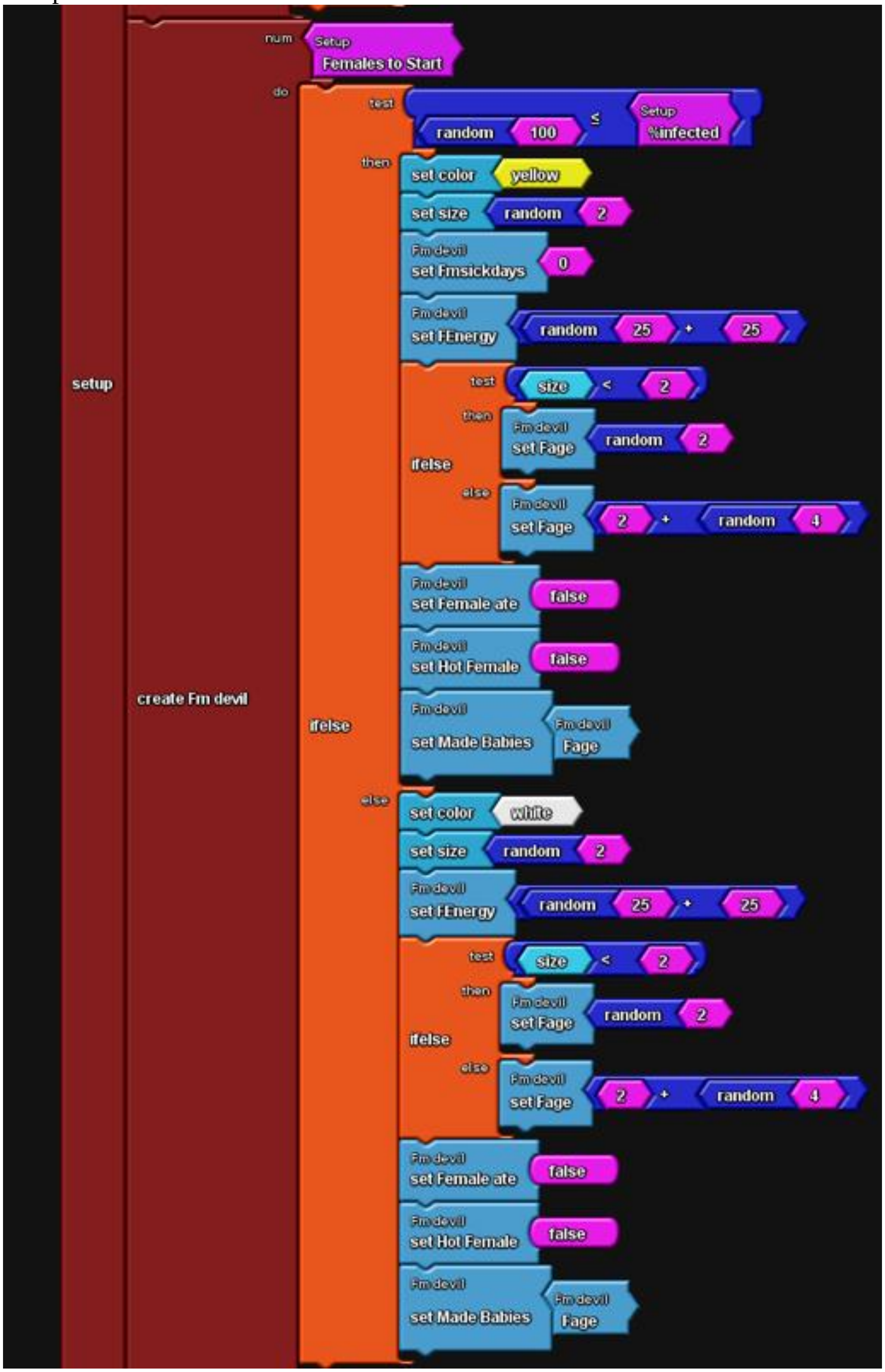

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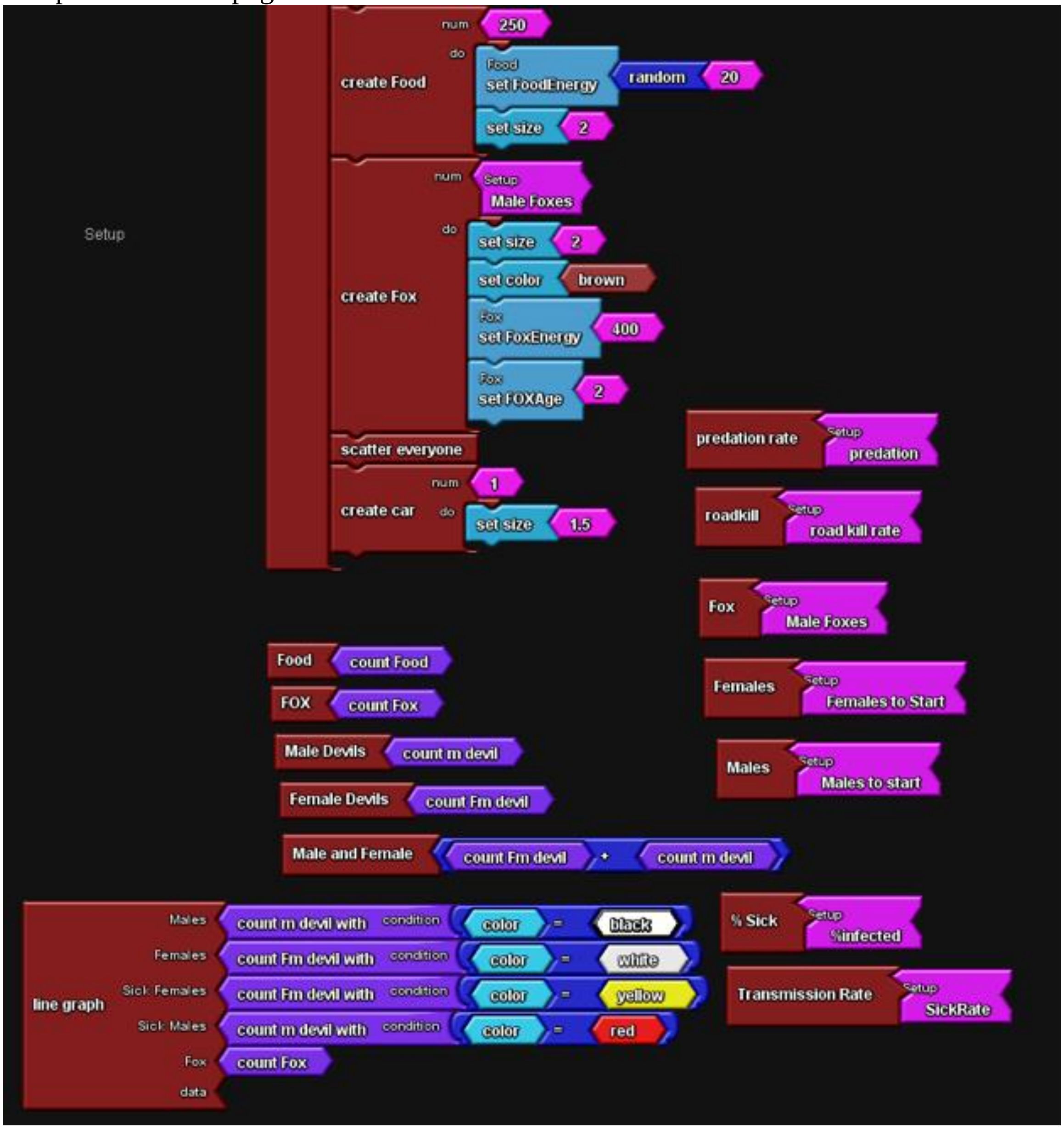
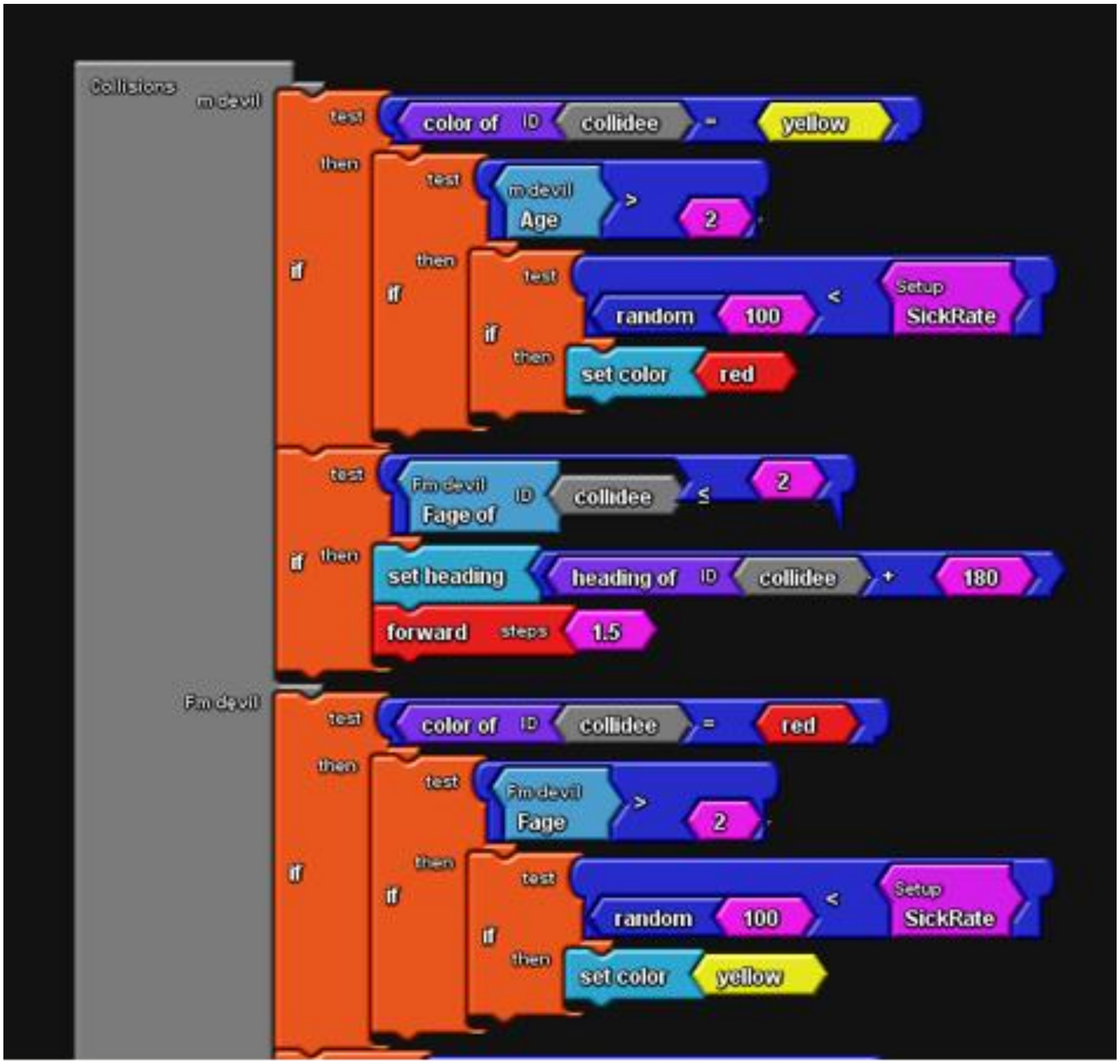


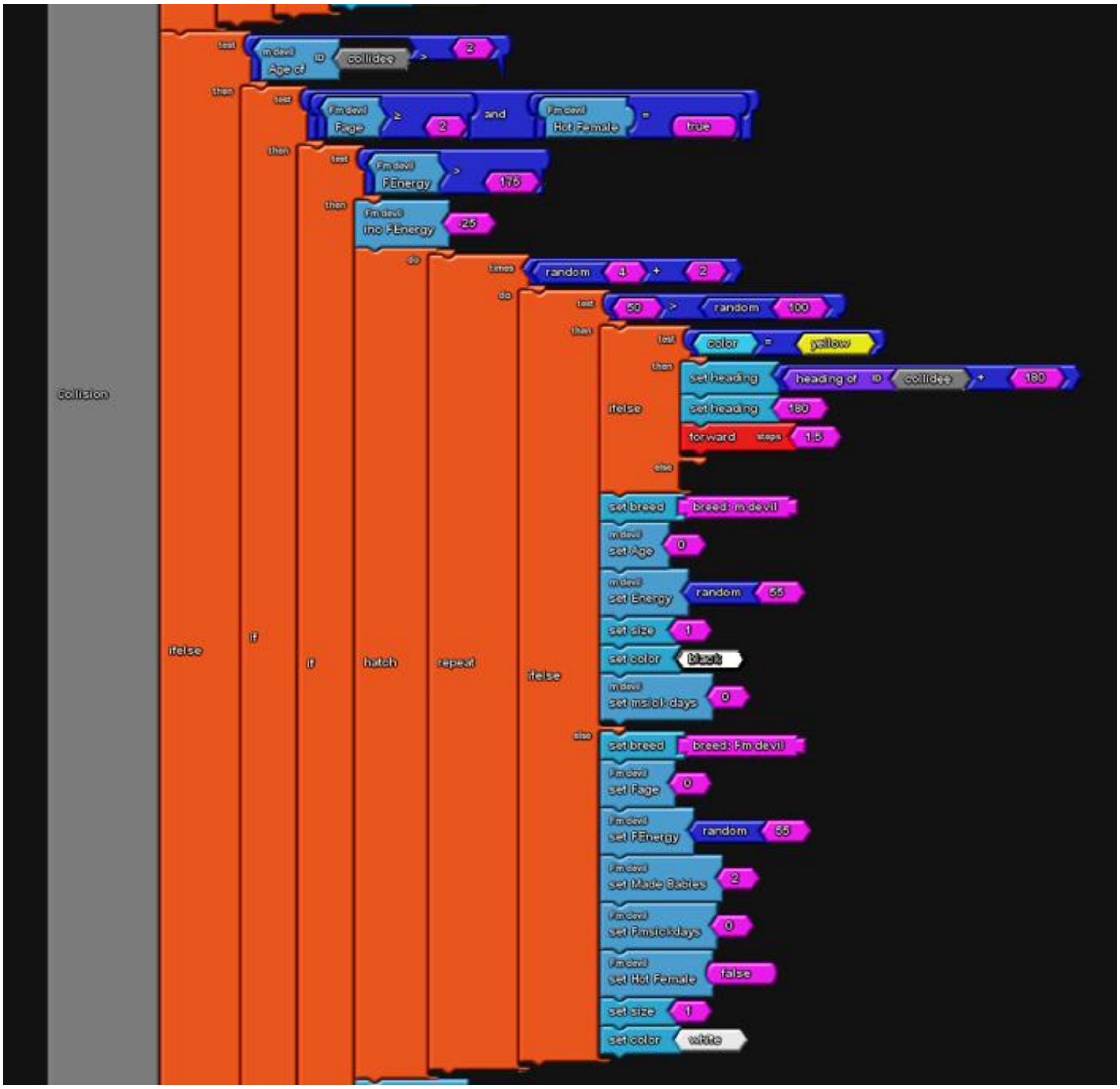
Runtime:


forever
m devil
m devil
move
m devil
Lose Energy
Fm devil
Fm devil
Ready to Make More
Fm devil
move2
Fm devil
Lose FEnergy
Food
Food
More Food
car
car
carmove
Fox
Fox
Fox move
Fox
More Foxes

Collisions with male and female devils:

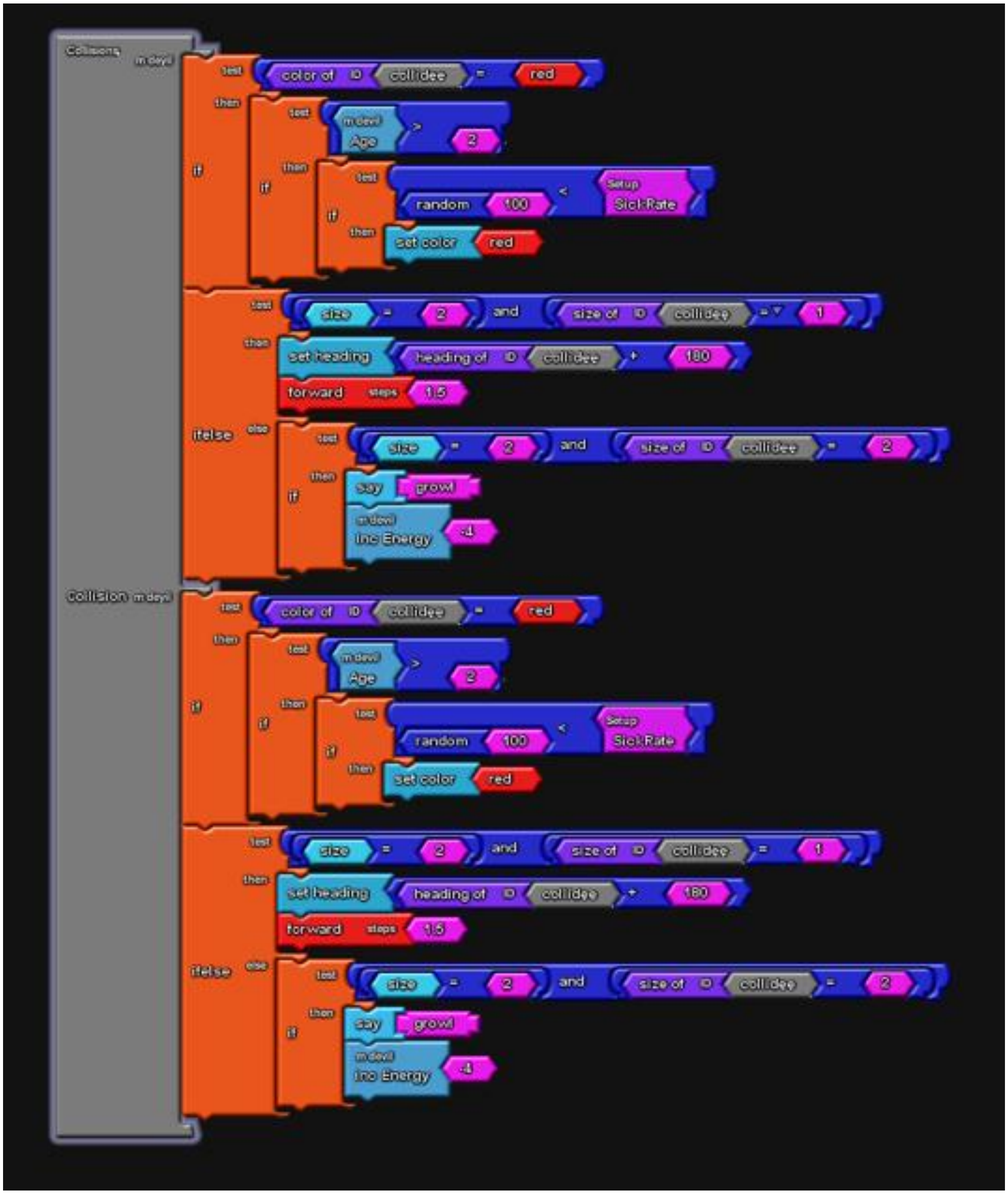


Collisions with male and female devils continued:

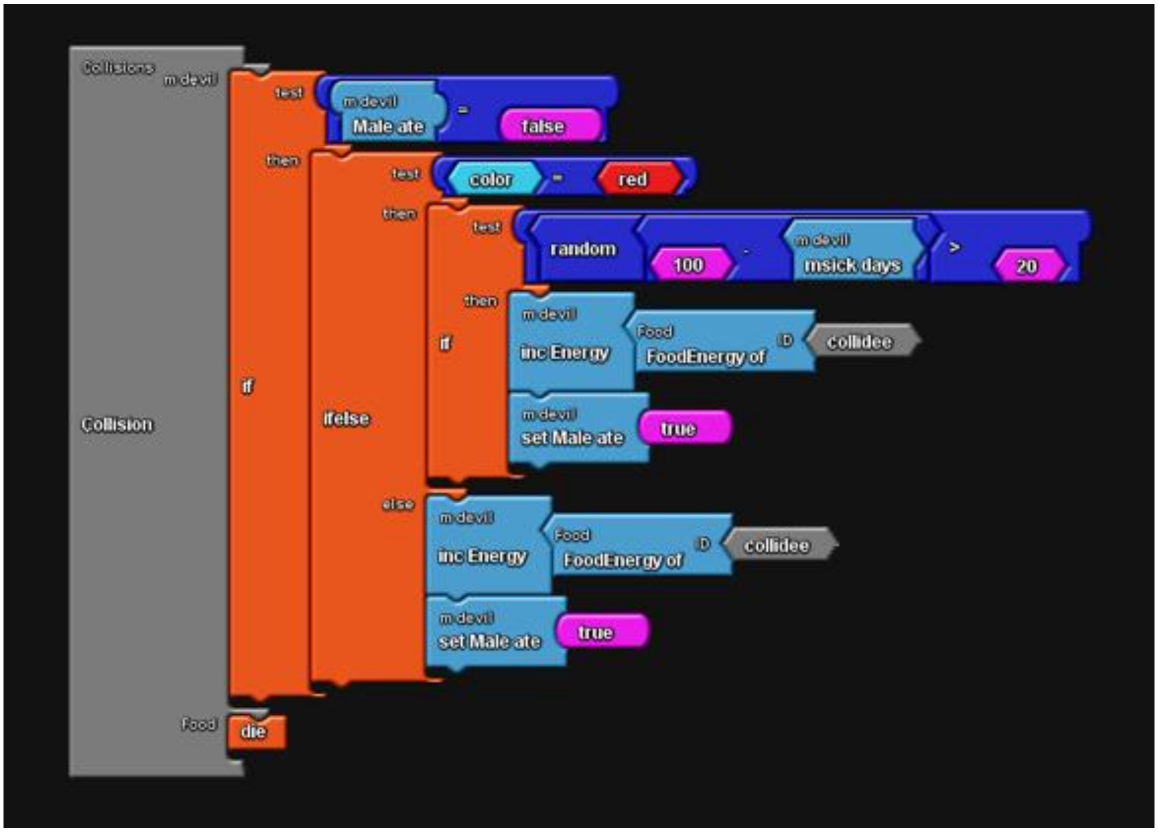


Collisions with male & female devils part 3:

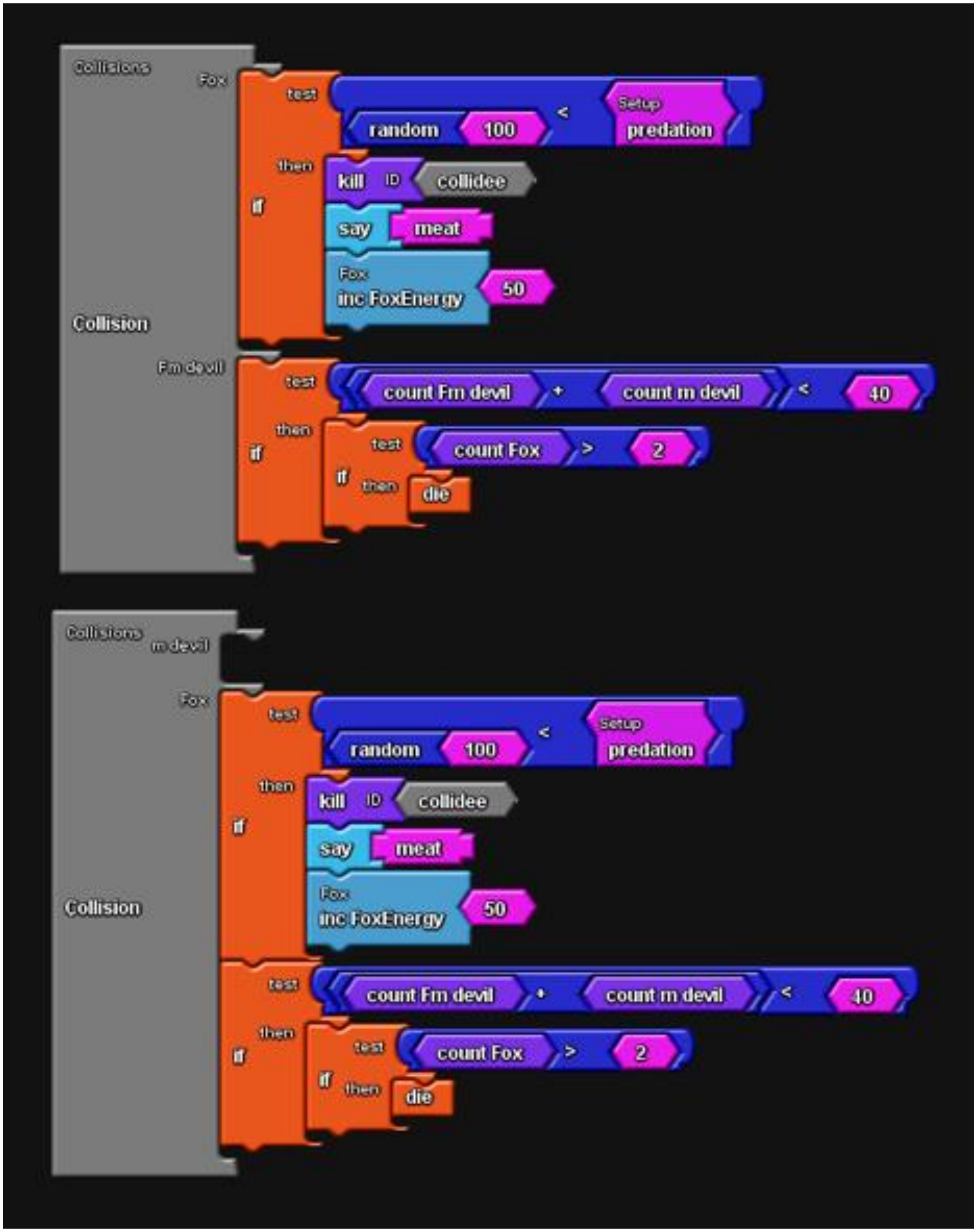
Collisions male to male devils:



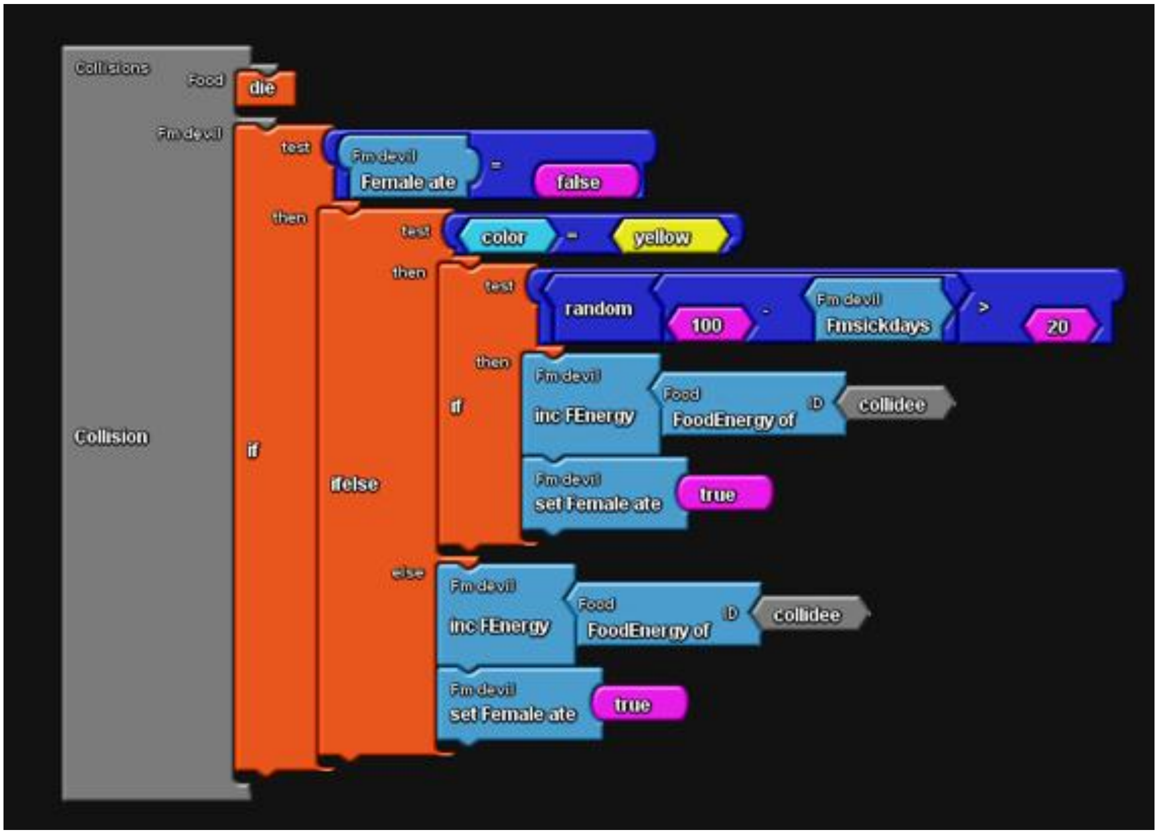
Collisions male devils and food:



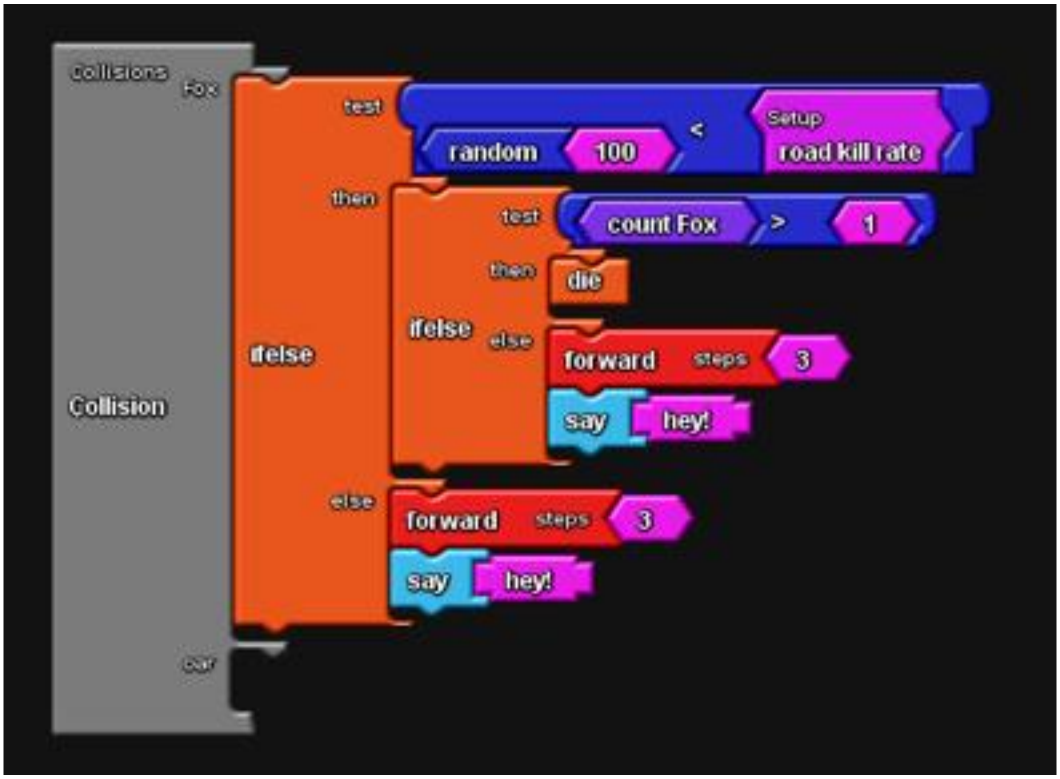
Collisions foxes and devils male and female:



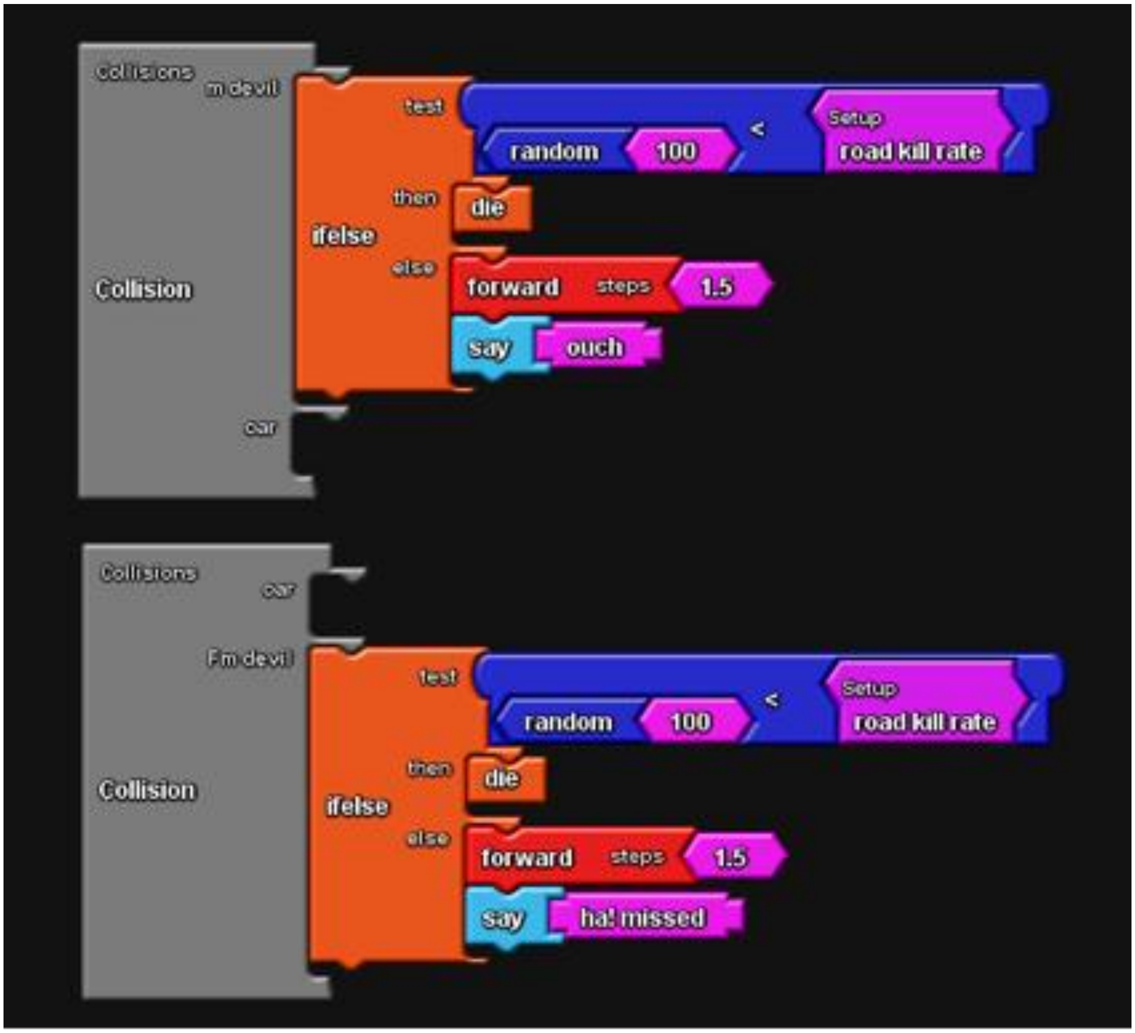
Collisions food and female devils:



Collisions foxes and cars:

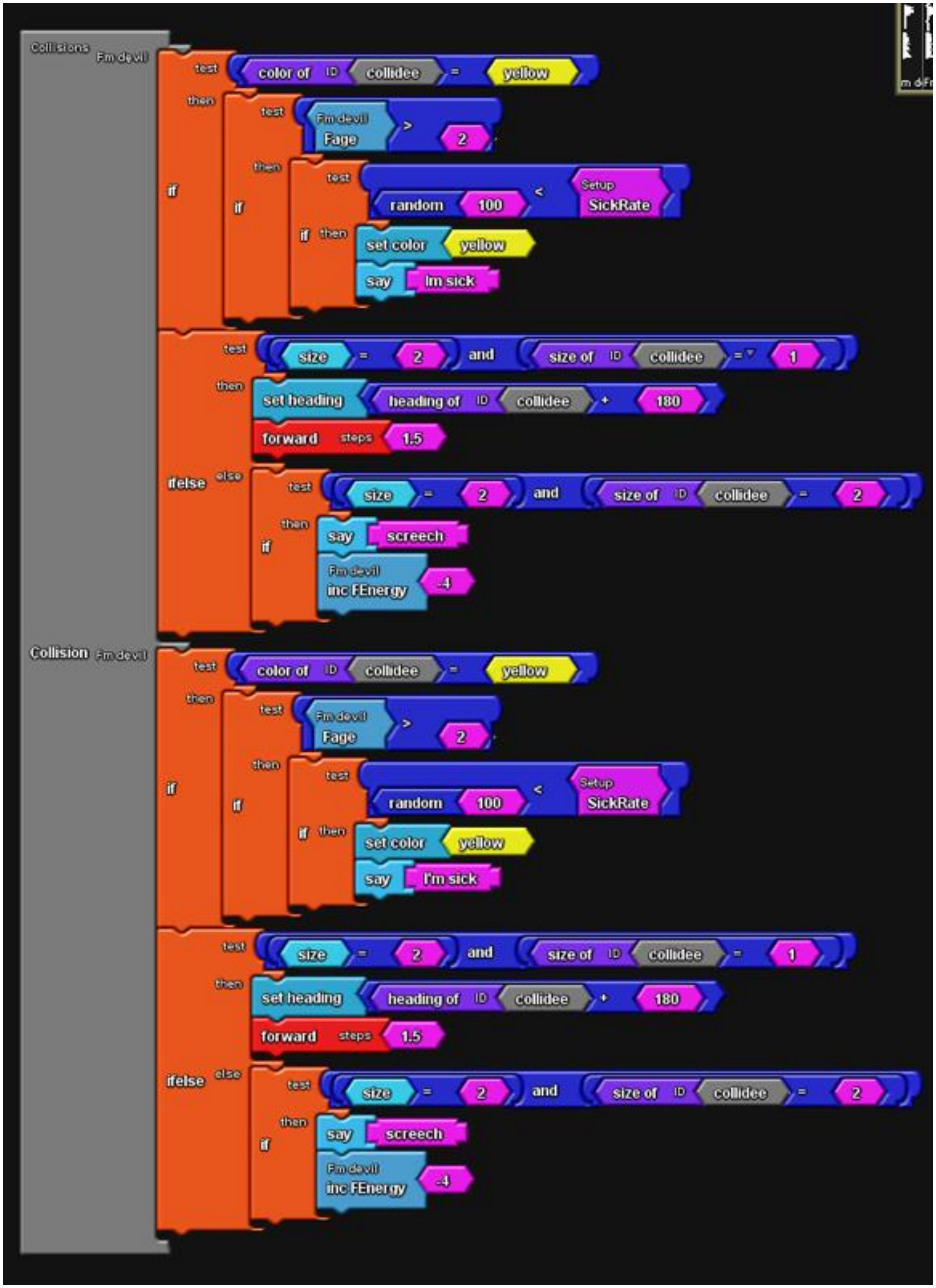


Collisions devils and car:

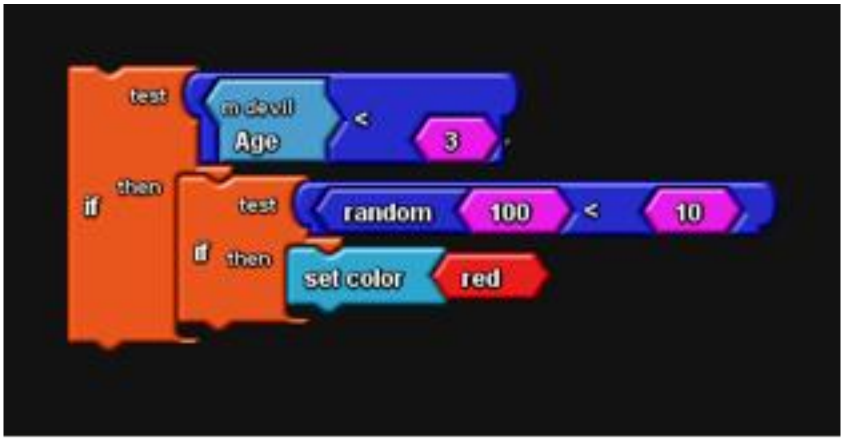


Collisions food and car:

Collisions female to female devils:



Male devil turn red when sick:



Spaceland:

Buttons under Spaceland:

Things to model when we continue this project next year

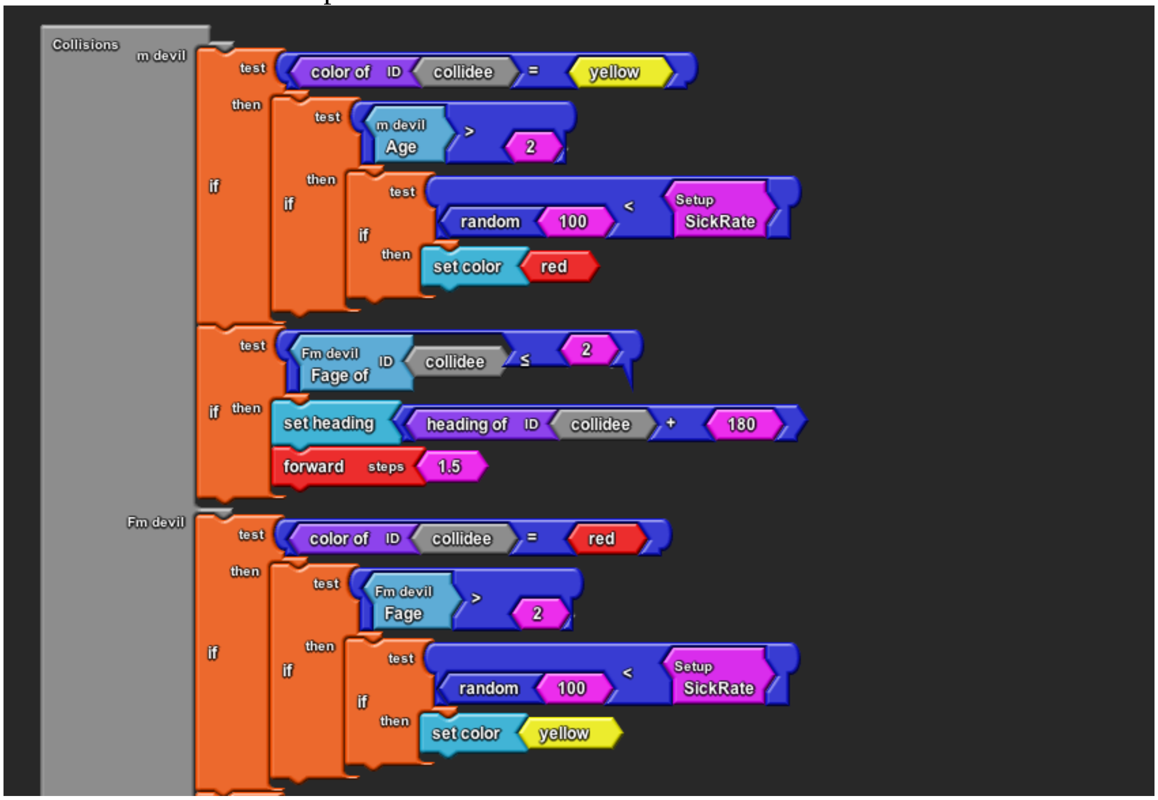
Next year we'd like to be able to track the progress of the DFTD across Tasmania, and include terrain in the program too. We'd like to directly contact more researchers in Tasmania. We'd like to program that the devils move around only at night. We figured out a way to calculate when in the cycles it is March, which is when the devils breed, but ran out of time to program this into our final model, though we have some examples below of things that we modeled on a subset but didn't have a chance to test out. We also played around with the definition of a cycle and tried it equal to an hour, but then it took too long to run through 10 years to see what would happen over time. We also think that a week or a month is too long for a cycle, so will probably try it to exactly equal a day per cycle.

As in many team projects, there can be different approaches to how to solve problems. Different ways to model energy loss, and death from the disease, for example. There was discussion on if food is a limiting factor for devils. In a general sense, food is limiting for any species because without food, they will die. But, in our research, we didn't find any studies that said that healthy devils died of starvation. Only that the devils with DFTD would eventually starve to death as the tumors would prevent food from getting down their throats. We found a different way to calculate age of death, but this too is somewhat arbitrary. We could do an if/then statement with 25% dying at age 5, 50% dying at age 6, 75% dying at age 7, and 100% dead by age 8, but we don't know the exact amounts that would die by each added year of age, just that they typically will die between the ages of 5 and 8 in healthy populations in the wild. On a similar model, we could show that 25% of sick devils will die by 3 months with the disease, 50% by 4 months, and so on so that 100% are dead at 6 months after getting the disease.

We wonder if gene therapy is possible to change devils slightly and make them resistant to DFTD while still keeping their nature.

We would like to have a stable model to show the devil's population decline from 1996 to present, and then see how long into the future it will take before they are extinct in the wild. Then, we'd like to model the insurance population and see how long it will take to re-establish the devil on Tasmania. There are approximately 170 "insurance devils", but they believe somewhere between 500-1700 will be necessary to be able to repopulate ([14]).

Male to female collision part 1:



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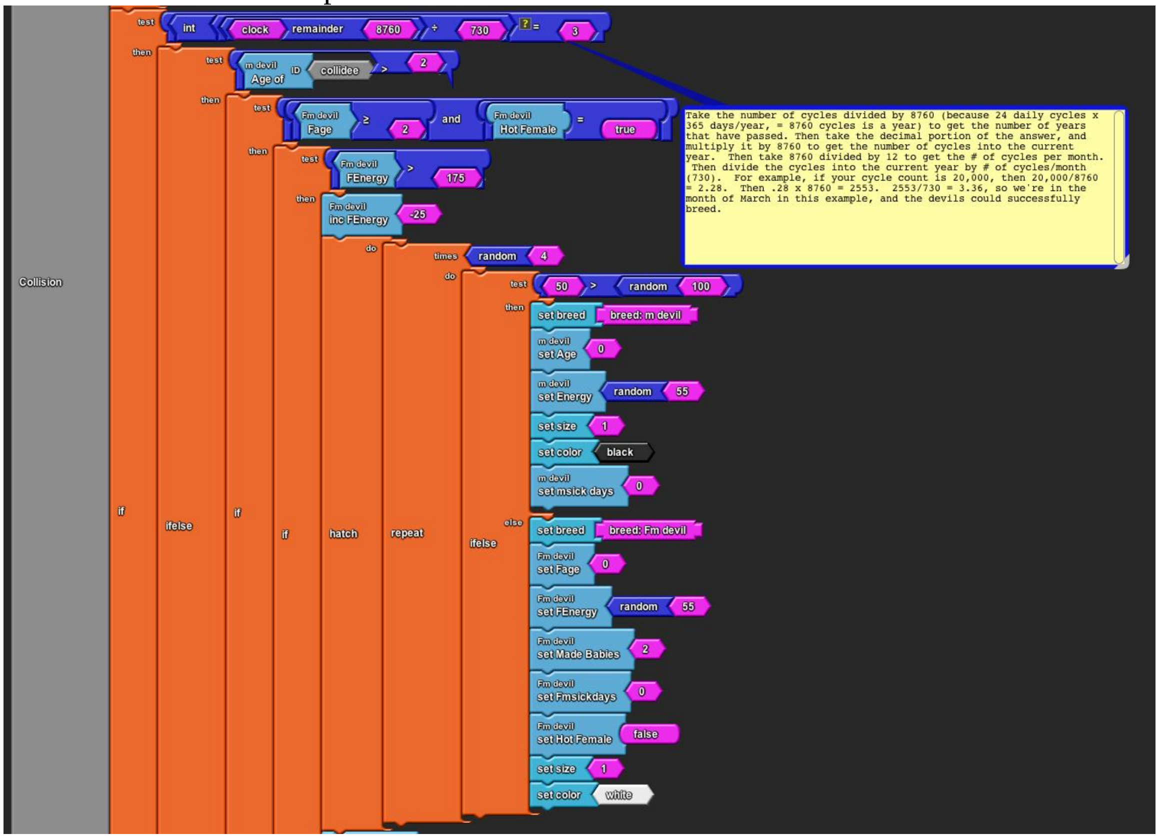

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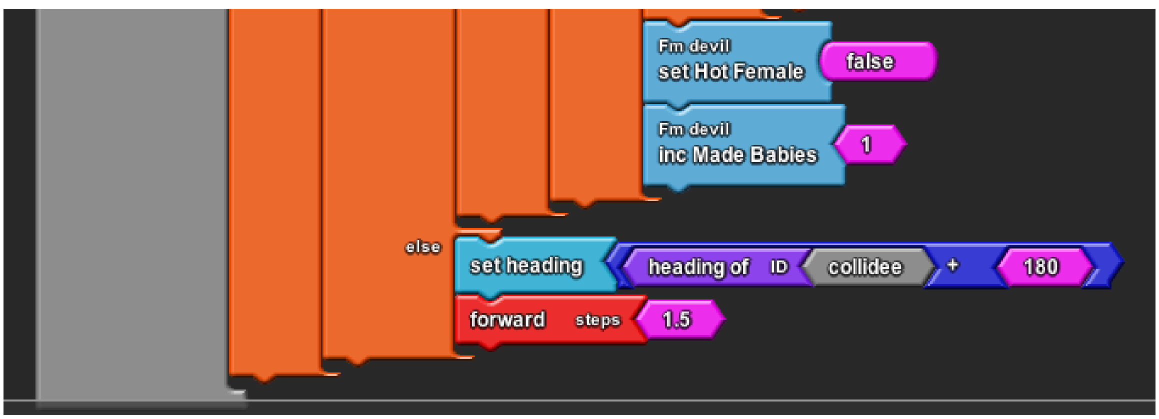
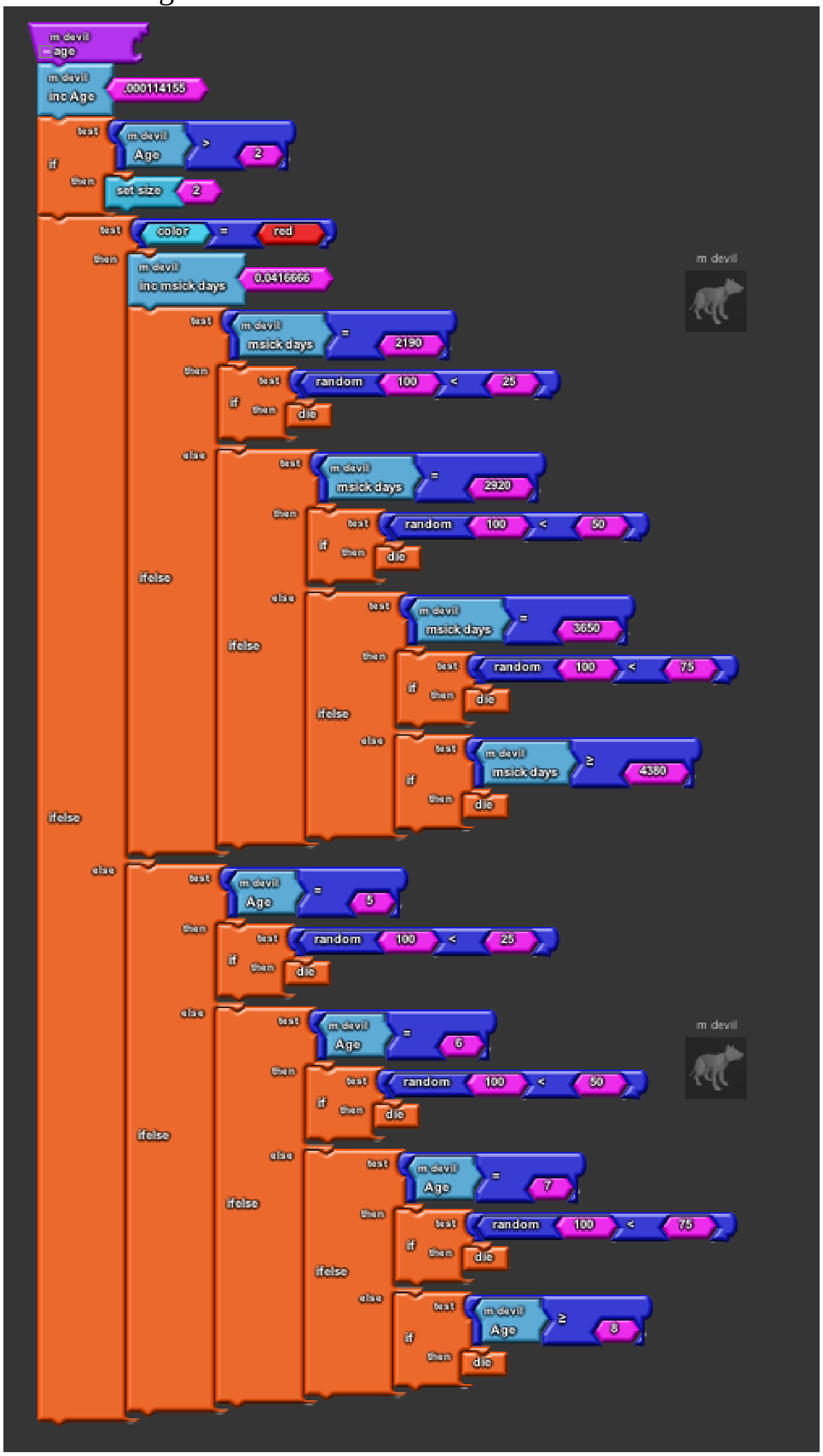
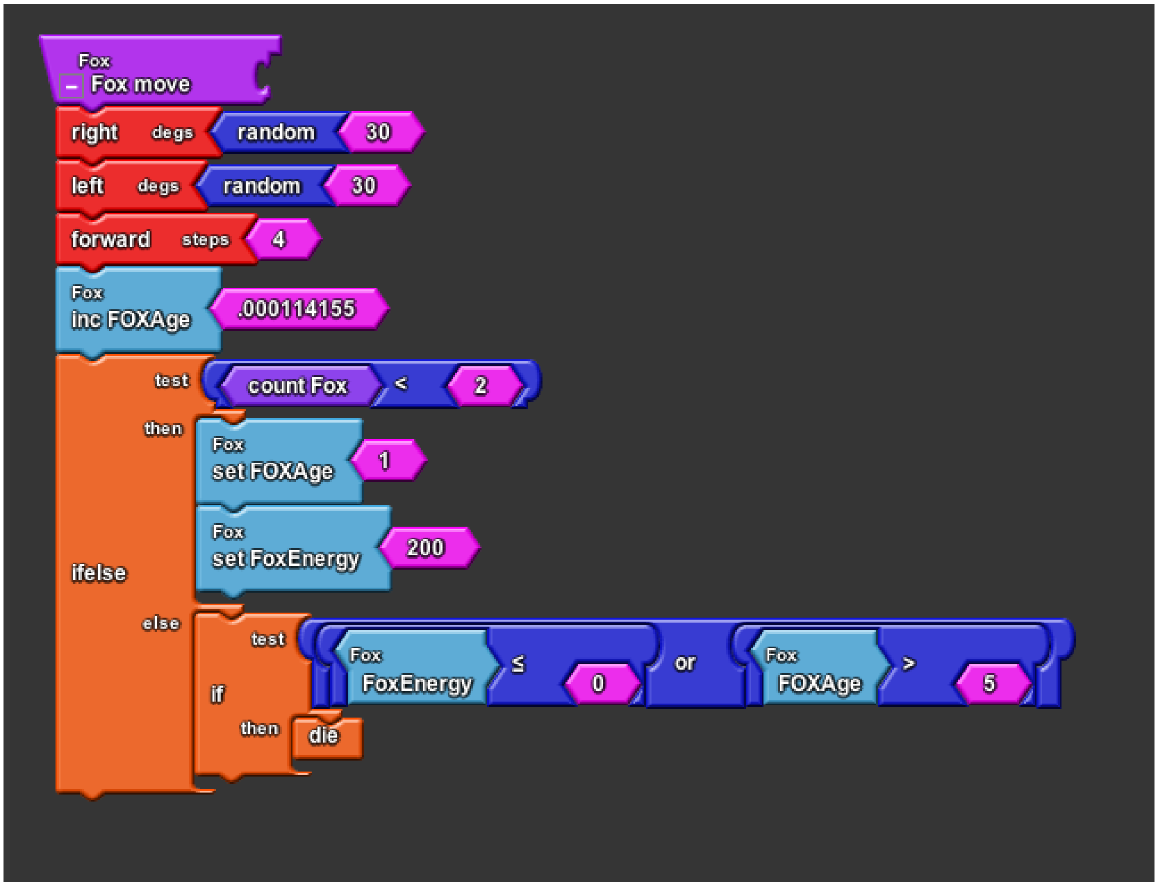


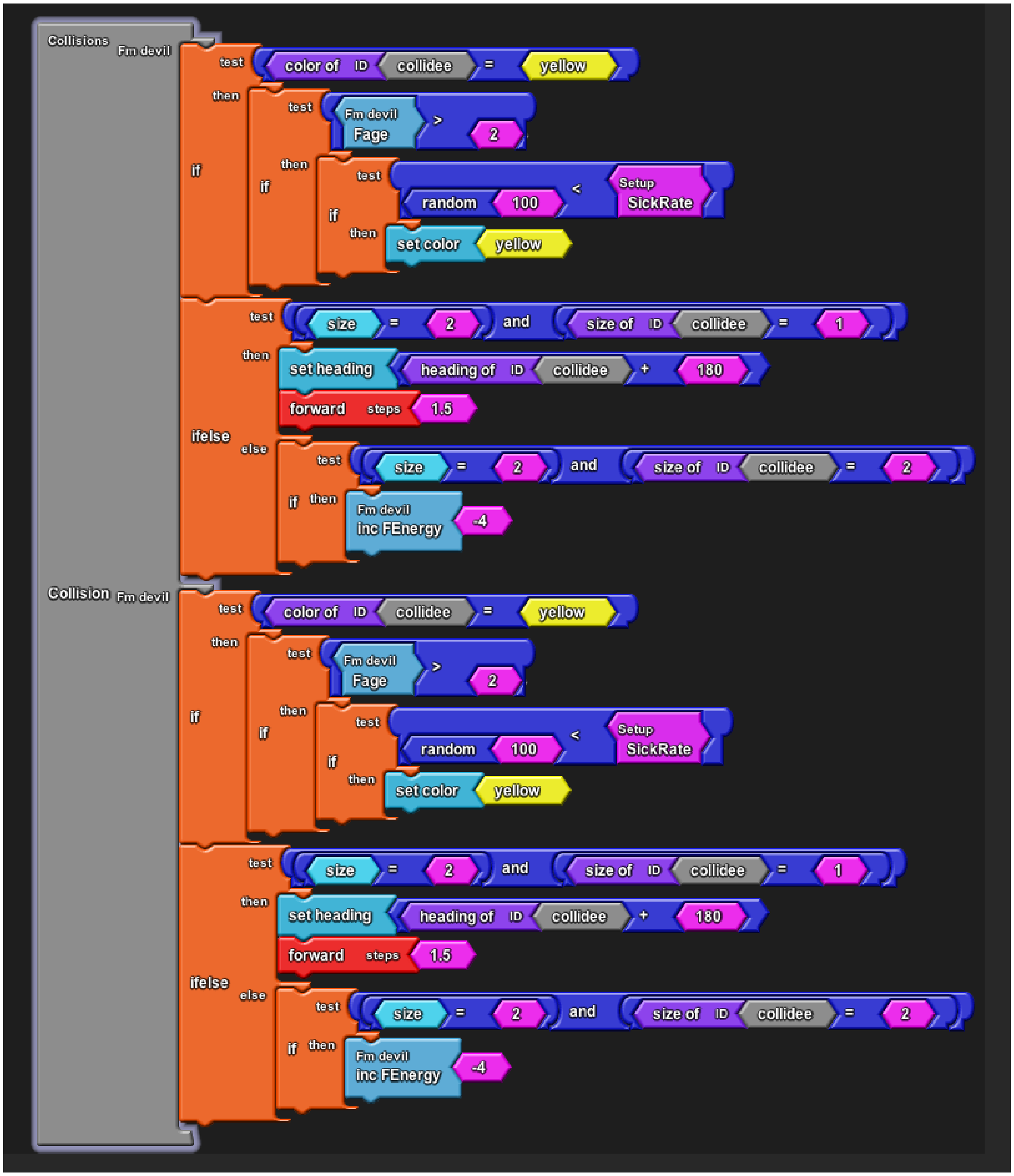
Male devil age:



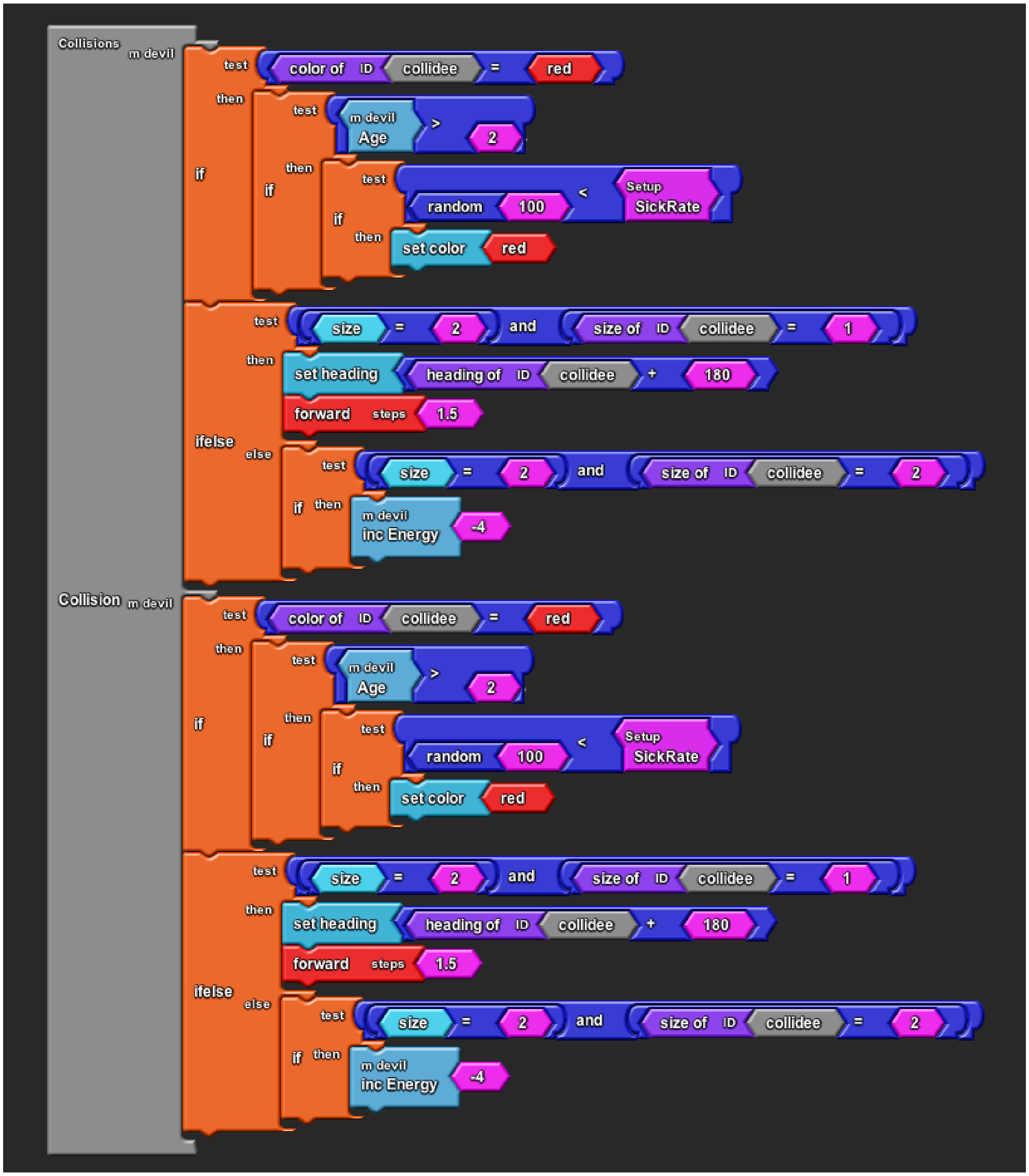
Fox Movement:



Female to female collision:



Collision male to male:



Car Speed to model 40 km per hour: