Philosophy 3334: Philosophy of Biology
Fall 2023
First homework assignment

ANSWER GUIDE

1) What does chromosomal crossing over have to do with how Dawkins defines what a gene is? In some species, crossing over does not occur and we could imagine species where it happened much more frequently per chromosome. How would this affect what a gene is on Dawkins view?

Crossing over affects the length of a gene. A gene has to be short enough to be expected to survive long enough to be affected by natural selection – i.e. multiple generations. If there is no crossing over at all (for example, on the mammalian y chromosome), then entire chromosomes are passing on intact to offspring and so entire chromosomes are genes. If crossing over were more frequent (many crosses per chromosome in the creation of the sex cell) then genes would have to be much shorter so that they have a lower chance of being broken up by recombination.

Question worth 1 points

2) For at least some behaviors, genes could potential "hard-wire" these behaviors in so that they are like involuntary reflexes. But in many species (like humans) many behaviors are not controlled directly by genes but rather the result of a decision by a brain. But brains often make decisions that are not good for the survival of the genes. So how can we explain why a gene would build a survival machine with a brain that can make decisions like committed suicide or using contraception?

What is favored by natural selection is a trait that is beneficial on average. Brains make it easier to learn and brains can also control the body in real time and this can have real advantages over hard-wired behavior. Sometimes the behaviors will be bad for the genes (like suicide). But as long as having a brain is on-average better than hard wired behavior, it is possible for brains to evolve.

Question worth 1 points

3) Imagine the following scenario: A species of carnivore is such that there are two different hunting strategies in the population. Strategy 1 is to pursue the 'group hunt' strategy of attacking big game which is only successful with help. Strategy two is to pursue the 'lone wolf' strategy of hunting smaller game which is always successful. When the time comes to get food, the hunters find themselves nearby another hunter. If a 'group hunter' meets another 'group hunter' they each receive 4 units of benefit. 'Lone wolf' always receives 2 units of benefit no matter who they meet. But if a 'group hunter' meets a 'lone wolf', then 'group hunter' gets 0 benefit while 'lone wolf' gets 2.

In other words, we have the following payoff matrix:

	Group hunter	Lone wolf
Group hunter	4,4	0,2
Lone wolf	2,0	2,2

Which of these two strategies, if any, is an evolutionarily stable strategy? Explain how you know.

ANSWER: Both strategies are evolutionarily stable. To determine if a strategy is stable, we assume it is played by 100% of the population and ask if it can be invaded by a mutant strategy.

Group hunter is an ESS because if everyone was playing group hunter, then everyone would be receiving 4. If a mutant Lone wolf came in, they would be paired against a Group hunter and would receive 2. Since 2 < 4, Group hunter is stable.

Lone wolf is also an ESS. If everyone was playing Lone wolf, then everyone would be receiving 2. If a mutant Group hunter came in, they would be paired with a Lone wolf and would receive 0 units of benefit. Since 0< 2, Lone wolf is stable.

Of interest (not part of an answer): This is a very famous game typically known as "The Stag Hunt." The best strategy is to play whatever strategy is currently in the majority and so unlike the Hawk-Dove scenario, whichever strategy is in the majority will take over the population and go to fixation.

Question is worth 2 points

4) Imagine a two-player game where individuals in the population are paired at random. There are two possible strategies: heads and tails. If both players play heads or both players play tails, then nobody gets any payoff. However, if a head is paired against a tail, then the head receives 4 units of payoff and the tail receives 6. In other words, we have the following payoff matrix:

	Heads	Tails
Heads	1,1	4,6
Tails	6,4	1,1

In fact, neither heads nor tails is an evolutionarily stable strategy.

4a) Explain why neither state is stable.

ANSWER: If everyone was heads, they would be getting 1 and then a mutant tails would get 6. If everyone was tails, they would be getting 1 and a mutant heads would get 4. Both can be invaded therefore neither is stable.

4b) Now imagine that the population is 80% heads and individuals are paired at random. What is the expected payoff of the heads strategy? And what is the expected payoff of the tails strategy?

Answer:
The expected payoff of Heads is Exp(H) = EO(H,H) x P(H) + EO(H,T) x P(T) = 1 x .8 + 4 x .2 = 1.6

The expected payoff of Tails is Exp(T) = EO(T,H) x P(H) + EO(T,T) x P(T) = 6 x .8 + 1 x .2 = 5

4c) Assuming that the payoffs represents reproductive fitness, over time, this population will reach a stable state. What is the percentage of heads and tails in this stable state? Show your work and explain how you know this state is stable.

[NOT NEEDED FOR ANSWER[If the population started at 80% Heads, then tails would be the better strategy and so tails would start increasing in the population. Tails would continue to increase until the payoff to heads and tails is the same. Analogous, if the population had a very large percentage of tails, heads would do better and increase in frequency until again they were the same.

ANSWER: The payoffs are the same when:

EO(H,H) x P(H) + EO(H,T) x P(T) = EO(T,H) x P(H) + EO(T,T) x P(T).

So in this case, 1 x P(H) + 4 x P(T) = 6 x P(H) + 1 x P(T)

Therefore 3 x P(T) = 5 x P(H). So the ratio of P(T) to P(H) = 5:3 so P(T) = 5/(5+3) = 5/8

Alternatively,
setting P(T) = 1-P(H) we get 3 x [1-P(H)] = 5 x P(H). So 3 - 3 x P(H) = 5 x P(H). So 3 = 8 x P(H) so P(H) = 3/8.

Thus the equilibrium state has 3/8 Heads and 5/8 Tails (in this state, both strategies have an expected payoff of 23/8).

Question is worth 3 points

5) What would be the coefficient of relatedness between me and my mother's half-sister? (Half-siblings share one parent but not both). Explain your answer.

Answer:
Each parent/offspring reproduction event reduces relatedness by 1/2. In this case, our most recent common ancestor would be my grandparent. Thus the generation distance is 3 (2 up then 1 down) and thus r=1/8. It is also acceptable to point out that half-sisters are r=1/4 (they share one parent) and since I am 1/2 to my mother, I am 1/8 to her half-sister.

Question is worth 1 points

6) In each of these three following scenarios, explain which trait will be favored by natural selection and why. If you think particular numbers do or do not matter, your answer should explain why they do or do not matter (in other words, show your work).

6a) Organisms of species 1 typically find themselves in groups of size 5 on average. Organisms in this species leave their homes soon after they are born and so are no more likely to be nearby kin than nearby more unrelated organisms. When a predator attacks, there are two possible strategies: Strategy A is to simply run away. If you do so, you might survive, you might not. The predator might kill another organism in your group, it might not. Maybe everyone will get away, but the predator never catches more than one member of your group. If you just try to run away everyone else will too. Each of you has a 10% chance of being caught by the predator and there is a 50% chance you will all get away. Strategy B is to send up an alarm call first which tends to cause the predator to focus on you but warns the other members of the group and so they get away. Now the chances of you being caught are 20% but everyone else always gets away so the chances that you all get away are 80%.

Will natural selection favor strategy A or strategy B?

Answer:
Natural selection will favor the trait that on average, maximizes the number of copies of the gene in the population.

With strategy A we have you plus four others each with a .9 chance of survival. You have r=1 to yourself (one copy of your genes) the others are random so r=0 for them. So the total number of copies of your genes surviving will be:

1 x .9 + 0 x .9 + 0 x .9 + 0 x .9 + 0 x .9 = .9

For strategy B, your chances go to .8, the others' chances go to 1. So the expected number of copies of your genes surviving is:
1 x .8 + 0 x 1 + 0 x 1 + 0 x 1 + 0 x 1 + 0 x 1 = .8. So strategy A is better.

(Alternatively): Since the other members of your group have, on average, zero relatedness to you, it doesn't matter what the effect of your behavior is on them. All that mattes is the effect it has on you. Since a 10% chance of death is better than a 20% chance of death, natural selection will favor strategy A (run away).

6b) Organisms of species 2 live in family units consisting of a mother and all her children who always share the same father. Sometimes there are 2 children, sometimes 3, sometimes 7, etc. On average, the group consists of 5 individuals. When a predator attacks, there are two possible strategies: Strategy A is to simply run away. Each of you has a 10% chance of being caught by the predator and there is a 50% chance you will all get away. Strategy B is to send up an alarm call first which tends to cause the predator to focus on you but warns the other members of the group and so they get away. Now the chances of you being caught are 20% but everyone else always gets away so the chances that you all get away are 80%.

Will natural selection favor strategy A or strategy B?

Answer:

For strategy A, now we have r=.5 So the total number of copies of your genes surviving is: 1 x .9 + .5 x .9 + .5 x .9 + .5 x .9 + .5 x .9 = 2.7

For strategy B, the chances of survival change. The total copies of your genes surviving is:
1 x .8 + .5 x 1 + .5 x 1 + .5 x 1 + .5 x 1 = 2.8. So strategy B is better.

(Alternatively): An altruistic strategy is one that lowers the chances of survival of your body but raises the chances of survival of others bodies. This behavior would be favored by selection if the total benefits to your genes in other bodies outweighs the cost to the genes in your own body. An easy way to calculate this is to use Hamilton's rule: the altruistic strategy is better when r x b > c.

In this case, any recipient of the signal will be r=.5 to the signaler. The cost to the signaler is the reduced chance of survival – the chance of death increases from 10% to 20% so the cost is .1. The benefit to each recipient is the increased chance of survival. The chance of death goes from 10% to 0% so the benefit to each listener is .1. So for each recipient, r x b = .5 x .1 = .05. There are 4 recipients for a total weighted benefit of .2. This is greater than the cost (.1) so signaling (strategy B) will be favored by natural selection.

6c) Organisms of species 3 like to 'spread out' (relative to species 1 and 2) and so when predators attack the average group size is only 3. And often, but not always, they are near their kin. On average, the relatedness coefficient of their other group members is .2. When a predator attacks, there are two possible strategies: Strategy A is to simply run away. If you do so, the chance of being killed yourself is 10% and the chance of each other member of your group being killed is 10%. There is therefore a 70% chance you will all get away. Strategy B is to first send up an alarm call warning everyone in your group near enough to hear. The chance of being killed yourself is now 20%, but the other organisms will get away for sure meaning there is an 80% chance you will all get away.

Will natural selection favor strategy A or strategy B?

For strategy A, now we have r=.2 with two other individuals So the total number of copies of your genes surviving is: 1 x .9 + .2 x .9 + .2 x .9 = 1.26. For strategy B it is 1 x .8 + .2 x 1 + .2 x 1 = 1.2. So A is better.

(Alternatively): In this case, any recipient of the signal will be (on average) r=.2 to the signaler. The cost to the signaler is the reduced chance of survival – the chance of death increases from 10% to 20% so the cost is .1. The benefit to each recipient is the increased chance of survival. The chance of death goes from 10% to 0% so the benefit to each listener is .1. So for each recipient, r x b = .2 x .1 = .02. There are 2 recipients for a total weighted benefit of .04. This is less than the cost (.1) so signaling (strategy B) will NOT be favored by natural selection. Just running away (strategy A) will be favored.

Question is worth 3 points