IBO 2018, Tehran, Iran

Practical Exam "Evolution, Ecology & Behavior"

Student Code:

29th International Biology Olympiad

15-22 July 2018, Tehran, Iran

IBO 2018
Tehran, Iran

29th International Biology Olympiad
July 15-22, 2018

Practical Exam
Evolution, Ecology & Behavior

Total Points: **100**
Duration: **90 minutes**

General information

Total points: 100

Exam time: 90 minutes

Please check your student code in the box on the title page.
將檢查首頁框框中你的編號是否正確

Use answer sheet, which is provided separately to answer all questions.

The answers written in the question paper will not be evaluated.
將答案填寫在答案卷裡，若將答案寫在題目卷裡不給分

In order to use the flags (the signs on your desk) just put them in the flag stand located on the left wall of your desk.
若需要使用旗子(放在桌上)，將旗子放在桌子左側牆壁的旗子架上。

Please ensure that all the materials and equipments are available to you. If anything is missing, put your yellow flag in the flag stand no later that 15 minutes after the beginning of the exam. (Any complaints after 15 minutes will not be accepted)

確認所有的物品和儀器都有拿到。如果發現缺少那些東西，在考試開始的15分鐘內，將黃色旗子放到旗子架上(超過15分鐘後再反映將不予受理)

In case of emergencies put your yellow flag in the flag stand.
萬一發生任何緊急事情，將黃色旗子放到旗子架上。

No additional materials will be provided in any case of material loss during experiments.
實驗過程中若將物品遺失，將不再補發。

We suggest you to read the entire protocol before starting the experiments which helps you with time management.
建議在開始實驗之前先讀完整個實驗程序。

Stop answering and put down your pen immediately at the end of exam. Put the entire protocol with the answer sheet in the envelope. Our assistants will collect the envelopes.
考試時間到時馬上停止作答並將筆放下。將整份題目卷以及答案卷放在信封裡，助手會收走信封

Write each the indicated number in the cell next to it with your own handwriting.
將數字照樣寫在下面的表中(協助閱卷者分辨手寫的1和7)

1	
7	

Part A - ***Investigating a model of biological diversification***
*A*部分 - 探索一個生物多樣化過程的模式

There are around 10 million different species of eukaryotes on this planet. Including prokaryotes would increase our estimate of the number of extant species on our planet drastically. Understanding why there is so much diversity on Earth has been one of the central questions in evolution and ecology. Rainey and Travisano (1998) attempted to answer certain aspects of this question in the lab. As their model organism, they used a prevalent aerobic bacterium, *Pseudomonas fluorescens. ,*

地球上有約一千萬種真核生物，如果加上原核物種那地球的物種就更多。演化和生態的中心議題就是要瞭解地球上生物多樣性為何如此之多。科學家嘗試在實驗室來解答此一問題。他們用一種極常見的好氣性細菌，螢光假單胞菌來進行實驗。

Starting from a monomorphic population of *P. fluorescens*, they allowed bacterial cells to grow in a static broth culture, i.e., a beaker that is not shaking. The morphology of the ancestral population could be described as “smooth”, referring to the smooth colonies it would form on a petri dish. It has been shown that two other morphologies are possible in *P. fluorescens*: wrinkly spreader and fuzzy spreader (**Figure 1**).

從螢光假單胞菌的單態群體開始，科學家允許細菌細胞在靜態肉湯培養基中生長，也就是不搖晃的燒杯。祖先種群的形態可以被描述為“光滑的”，指的是它在培養皿上形成的光滑菌落。我們已經知道，在螢光假單胞菌中可能存在另外兩種形態：皺褶型和模糊型（Figure 1）。

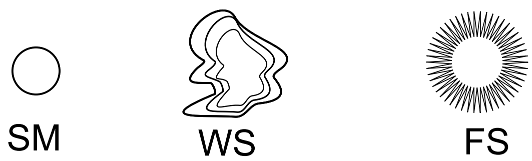

Figure 1: *The three different morphologies of P. fluorescens: 光滑 Smooth (SM), 皺褶擴散 wrinkly spreader (WS), and 模糊擴散 fuzzy spreader (FS).*

A bacterial lineage was established and evolved in the static environment for 7 days (in a beaker with 25ml of broth at 28 ºC). After 7 days, Rainey and Travisano transferred a sample of bacterial cells from the first lineage -i.e., the lineage that evolved for 7 days in the static environment - and established the second lineage. They allowed the first and the second lineage to evolve for another 7 days, in static and shaking environments, respectively. (At the end of each day, a subsample from the current beaker was transferred to a new beaker with fresh media to keep the lineages evolving.) (**Figure 2**).

一個細菌的支系在靜態環境中被建立並"演化"了7天（在28℃下，裝了25ml肉湯的燒杯中）。 7天後，Rainey和Travisano轉移了第一個支系的細菌細胞樣本，也就是說在靜態環境中進化7天的支系 - 並依此建立了第二個支系。他們允許第一和第二支系分別在靜止和搖晃的環境中再進化7天。（在每天結束時，把當時燒杯內的樣本取一小部分，轉移到具有新鮮培養基的新燒杯中，然後讓那個支系繼續進化）（Fig. 2）。

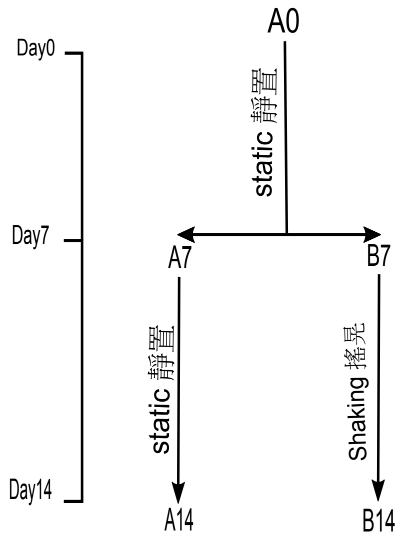

Figure 2: *The schematic representation of the experiment conducted by Rainey and Travisano*

Rainey與Travisano這個實驗流程的示意圖

Here, you will play the parts of Rainey and Travisano and try to make sense of the results observed by them. You are given plates from an experiment done in the exact same fashion as the one carried out by Rainey and Travisano. The plates are created by sampling from evolving populations at different stages (as shown in **Figure 2**).

現在你就是要重現Rainey與Travisano的部分實驗而且要試圖解釋。你會拿到與Rainey與Travisano一模一樣的菌盤，而這些菌落盤則取樣自根據圖二所示的不同族群演化階段。

Change in the phenotypic diversity

表型多樣性的改變

Count the number of different morphs you see on each plate (Assume each plate is representative of its original population). For each plate, you can calculate the level of heterogeneity (H) using this formula:

計算每個培養皿中不同型態菌落的數量 (假設每一個培養皿就代表原來的族群)。請你使用下面的公式來計算型態異質性(H)的程度。

$$H=1-\sum_{i=0}^{n}(f_i)^2$$

where f_i is the frequency of morph ***i*** （fj是i型態的比例）on the petri dish (培養皿) and ***n*** is the number of morphs present on the petri dish (n是培養皿中有幾種型態的菌落).

A-1) Based on the observed results on plates, fill the table 1 in the answer sheet. (Correct to two digits after decimal point).

根據以上觀察,將數據填入答案卷的表1中，計算到小數點後兩位。

Plate	SM (Count)	WS (Count)	FS (Count)	SM (Freq)	WS (Freq)	FS (Freq)	H
A0							
A7							
B7							
A14							
B14							

A-2) Based on the data obtained, indicate if each of the following statements is true or false with a "✓" in the answer sheet.

根據以上的觀察與數據整理，勾選"✓"下列敘述的對錯。

a) It is more likely that diversity is due to phenotypic plasticity rather than mutations.
型態多樣性非常可能來自表型可塑性，而不是突變

b) Static environment provides more ecological niches, which increases diversity.
靜置環境可以提供較多的生態棲位，因此可以提高型態多樣性

c) The observed diversity results from mutations that existed in the ancestral population.
以上觀察到的型態多樣性是由原始族群就已經存在的突變所造就的

d) Larger subsamples result in higher heterogeneity.
換到新培養基的取樣量越大就會造就越高的型態異質性

e) Using bacteria is preferable for conducting this experiment due to short generation time and large population size.
因為世代短,族群龐大,所以細菌很適合被拿來做這種實驗

A-3) Assuming that there are only three bacterial morphs, calculate maximum achievable heterogeneity:

假設我們現在只有三種菌落型態，請計算可能達到的型態異質性的最大值

PART B

Investigating a model of population evolution 探索族群演化的模式

One of the main models for studying population genetics is the Wright-Fisher model (named after two of the founding fathers of the modern evolutionary theory, R. A. Fisher and Sewall Wright).

族群遺傳學中有一個重要的數學模式是由賴特-費雪所提出來的。

In its simplest form, the model assumes a population with a fixed number of haploid individuals. Individuals are asexual and simply make copies of themselves to reproduce. In order to create the next generation, one individual is randomly selected from the current generation and contributes one offspring to the next generation. This process is repeated until the next generation reaches the same size as the current one. Note that some individuals can be picked as parents for the next generation more than once by chance alone. After this step, the next generation replaces the current generation. This entire process is repeated to create future generations sequentially one at a time.

這個數學模式最簡單的型式是這樣的：假設一個族群具有固定數量的單倍體個體。這些個體行無性生殖，而且只複製自己來繁殖。為了要產生下一代，一個個體會被逢機性地從現存世代中被挑出來，然後再貢獻一個個體給下一個世代。這樣的過程會一再重覆直到下一世代達到與現存世代一模一樣的個體數。請留意，有一些個體被隨機挑出來當親本的機會會超過一次。經過這個階段以後，下一個世代就會取代目前這個世代。整個過程一再重覆就會漸漸造就未來的族群（們）。

If all the individuals in a population have the same fitness, then it is equally likely for each one to be picked as a parent, but if their fitness differ, then sampling process is weighted so that the fitter individuals are more likely to be picked.

如果一個族群內的所有個體都具有一樣的適存度，那麼每一個個體應該都有均等的機會被挑出來當親本。但如果它們之間的適存度有差別，那麼適存度比較好的個體就比較有機會被挑出來。

On your laptop, there is an application with shows the expected results from a Wright-Fisher model (On your desktop, go to \IBO2018\Task2 and double-click WF_model.py and wait for the application to start). There are 4 variables you can play with. The sliders allow you to change the values for each variable. After you have chosen the desired values for each parameter, simply click on <Simulate> to see a how heterogeneity (*H*) changes over time in a Wright-Fisher model, given the chosen parameters. (See the formal definition of *H* in **Part A**)

在你的筆電上有一個應用程式顯示賴特-費雪理想族群模式的期望值 (打開桌面上的\IBO2018]\Task2然後在WF model.py上按兩下，等待程式啟動)。應用程式中有四個變數可以操作。滑動一下就可以改變每一個變數的值。當你選擇你想要的每一個參數的數值以後，就按simulate看看你所選擇的參數條件在賴特費雪模式下，異質性(H)會如何隨著時間變化 (看Part A了解H的定義)

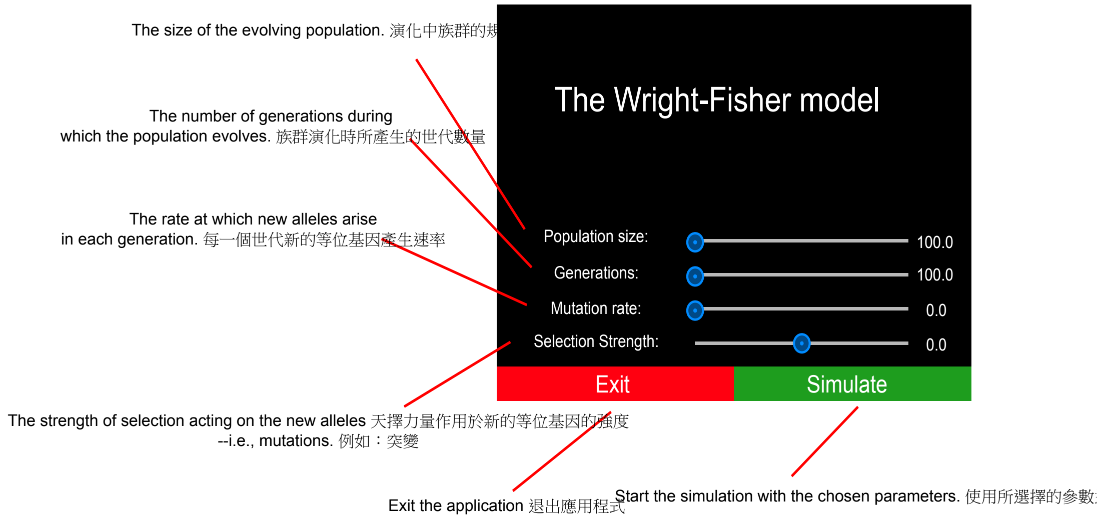

***Figure 3:** The interface of the Wright-Fisher model app.*
賴特-費雪理想族群模式應用程式的介面

Using this application, answer the following questions (Keep in mind that the behavior of the model is purely a function of the given parameters).

使用這個應用程式回答以下問題 (請記得這個數學模式的行為只是根據所具有的參數條件所產生的)

B-1) indicate if each of the following statements is true or false with a "✓" in the answer sheet.

請勾選下列敘述的對錯

A) Increasing the number of generations alters heterogeneity at equilibrium.
增加世代數就可以在平衡狀態下改變異質性(或雜合度)

B) Shrinking population size **does not** increase heterogeneity at equilibrium in any parameter set.
在平衡狀態,不管在什麼樣的參數設定下，族群規模下降,不會增加異質性

C) Decreasing population size accelerates achieving equilibrium heterogeneity.
降低族群規模可以加速達到平衡狀態下的異質性

D) Increasing mutation rate accelerates achieving equilibrium heterogeneity
增加突變率可以加速達到平衡狀態的異質性

E) When there is no mutation, increasing selection strength decreases heterogeneity at equilibrium.
如果沒有突變，增加天擇的強度就會降低平衡狀態的異質性

B-2) Indicate which of the following equations about equilibrium heterogeneity best fit with simulation results. (*N* is population size and *u* is mutation rate.)

以下哪一個有關平衡狀態下的異質性公式最吻合你的模擬結果？(*N*是族群規模*u*是突變率)

A) $H=\frac{4Nu}{1+4Nu}$

B) $H=e^{-4Nu}$

C) $H=\frac{2N}{N+4u}$

D) $H=1-\frac{1}{2N}$

$-2Nu$

E) $H=\frac{1-e^{-2N}}{1-e}$

PART C

Investigating the feeding behavior in Drosophila melanogaster larva
觀察果蠅(*Drosophila melanogaster*)幼蟲的覓食行為.

There are two forms of fruit flies' larva: active rovers and sedentary sitters. Active rovers maneuver through the medium in search for food, while sedentary sitters do not. It seems that these foraging strategies is genetically determined.

現在有兩種型式的果蠅幼蟲：好動及不好動者。好動者在培養皿中到處尋找食物，而不好動者則反之。這些覓食策略似受到遺傳的決定。

In a series of videos on your laptop (\IBO2018\Task3), you can see the different types of larva in a population for five consecutive generations (Gen1 to Gen5).

在電腦一系列的影像中，可以觀察到五個連續世代，每一世代族群中兩種不同覓食型態的幼蟲。

C-1) Using the film from the fruit flies larva, complete the table below (Use the same method as part A to calculate *H;* Correct to two digits after decimal point).
觀察影片中果蠅幼蟲的行為，將結果填入下表(用和A部分同樣的方法計算*H*,到小數點後兩位數)

Note: For a larva to be counted as a sitter, its **head-tail axis** should **stay in or touch the boundary** of a food patch (two **dark grey circles** in the footage correspond to two food patches) for the entirety of a movie clip.

注意：不好動幼蟲的定義，是指在整部影片中，幼蟲整個身體一直停留在食物區塊中，或幼蟲雖然在食物區塊外，但整個身體(由頭至尾整條軸線)側邊接觸到食物區塊邊緣(影片中兩個深灰處的圓圈即是食物區塊)。

No. of generation 世代數	**Sitters (count)** 不好動者**(**數量**)**	**Active rovers (count)** 好動者**(**數量**)**	**Sitters (freq)** 不好動者**(**比例**)**	**active rovers (freq)** 好動者**(**比例**)**	***H***
1(第**1**代**)**					
2(第**2**代**)**					
3(第**3**代**)**					
4(第**4**代**)**					
5(第**5**代**)**					

C-2) Based on the results indicate if each of the following statements is true or false with a “✓” in the answer sheet.
根據結果，在答案卷上勾 “✓” 選下列敘述的對錯.

A) The fruit fly larva foraging behavior follows the optimal foraging theory, which means in each generation the best feeding strategy will be chosen according to the environmental factors.
果蠅幼蟲覓食行為遵循最適覓食策略,就是在每一世代最佳覓食策略都受到環境因子的篩選.

B) The fruit fly larva foraging behavior follows conditional strategy, which is a mechanism that gives individuals the ability to alter their behavior, in this case foraging behavior between sitter and rover.
果蠅幼蟲的覓食行為符合條件式策略，也就是說個體有能力改變其行為，在本實驗中就是指好動與不好動幼蟲行為的改變。

C) The results are consistent with negative frequency-dependent selection.
這個結果與佔少數比例者在天擇中佔優勢的預測是一致的.

D) Assuming negative frequency-dependent selection is acting on the foraging strategies, none of the strategies can go to fixation in a population.
假設佔少數者在天擇中佔優勢會影響覓食策略,則在一個族群中沒有任何一個策略會被固定.

We can predict the change in the size of population over time by either considering the population itself, or taking into the effect of biological interactions, such as competition,

on the population dynamics. Below two models are introduced which represent these two approaches when considering the way a population changes over time.
考量族群本身，或納入生物交互作用(例如競爭),對族群動態的影響,我們可以預測族群大小隨時間的變化.下列提供的兩種模式代表上述兩種方式,來了解族群隨時間的變化.

I: discontinuous model of logistic growth:
非連續性對數成長模式.

$$N_{t+1} = N_t + rN_t\left(1 - \frac{N}{K_t}\right)$$

N_t: population size in generation t.
N_t : t世代的族群數
r: intrinsic per capita rate of population growth.
r. 內在單位個體族群成長率
K: carrying capacity.
K: 乘載量.
Note: This model is applicable for both active rovers and sitters.
注意: 此一模式適用於好動者與不好動者兩種型幼蟲。

II: discontinuous model of competition for sitters and active rovers (S, R):
好動者與不好動者之非連續性競爭模式(S.R):

$$S_{t+1} = S_t + r_S S_t\left(1 - \frac{S_t + a_{SR} R_t}{K_S}\right)$$

$$R_{t+1} = R_t + r_R R_t\left(1 - \frac{R_t + a_{RS} S_t}{K_R}\right)$$

S_t: population size of sitters in generation t.
S_t:不好動者在t世代之族群大小.
R_t: population size of rovers in generation t.
R_t:好動者在t世代之族群大小.

r_S: intrinsic per capita rate of population growth of sitters.
r_S:不好動者單位個體族群成長率.

r_R: intrinsic per capita rate of population growth of rovers.
好動者單位個體族群成長率.

K_S: carrying capacity for sitters.
不好動者之族群乘載量.

K_R: carrying capacity for rovers.
好動者之族群乘載量.

α_{RS}: effect exerted by sitters on rovers through competition on population growth.
好動者受到不好動者的競爭，影響好動者的族群成長.

α_{SR}: effect exerted by rovers on sitters through competition on population growth.

不好動者受到好動者的競爭,影響不好動者的族群成長.

C-3-1) Complete the table below based on model I and model II. Parameters of model are as follow (Correct to two digits after decimal point):
根據模式I及II,將數據填入下表,模式各參數如下(數字需包括小數點後兩位):

Model I:

r	3
K	500

Model II:

r_S	3	r_R	2
k_S	500	k_R	500
α_{SR}	0.1	α_{RS}	0.1

	Model I 模式 **I**	**Model II** 模式 **II**	**Model II** 模式**II**
No. of generation 世代代號	**Sitter (count)** 不好動者**(**數量**)**	**Sitter (count)** 不好動者**(**數量**)**	**Rover (count)** 好動**(**數量**)**
0	**184.00**	**184.00**	**262.00**
1			
2	**427.79**	**343.22**	**408.41**
3			
4	**196.94**	**120.45**	**381.17**
5			
6	**371.71**	**539.93**	**368.38**
7			

8	**34.89**	**571.68**	**459.81**
9			
10	**424.04**	**459.64**	**522.19**
11			
12	**182.86**	**516.81**	**497.54**
13			
14	**432.68**	**589.09**	**510.47**
15			

We have conducted a more extensive study to investigate the long-term change in the frequency of feeding strategies in *D. melanogaster* larva. The results of this study are shown in the table below.

研究人員進行一項更深入的研究,來探討長時期果蠅幼蟲取食策略頻度之變化。其結果如下表。

C-3-2) Calculate frequencies of feeding strategies predicted by model I and model II and fill the table below (For model I, since we have rovers in the population in addition to the sitters, to calculate the frequency of the sitters divide the number of sitter by 2 × K); Correct to two digits after decimal point).

分別根據模式 I與模式II，預測兩種覓食策略出現的頻度，並填入下表(在模式I中，由於除了不好動者外,尚有好動者.故要計算不好動者出現的頻度,需將不好動者的數量除以2K);答案需到小數點後兩位,

	Result of our study 研究者的結果	Prediction of model I 模式I的預測值	Prediction of model II 模式II的預測值	Prediction of model II 模式II的預測值
No. of generation 世代代號	**Sitter** 不好動者	**Sitters** 不好動者	**Sitter** 不好動者	**Active rover** 好動者
0	**0.41**			
1	**0.54**			
2	**0.61**			
3	**0.62**			
4	**0.91**			

5	**0.32**			
6	**0.68**			
7	**0.63**			
8	**0.46**			
9	**0.27**			
10	**0.84**			
11	**0.67**			
12	**0.47**			
13	**0.39**			
14	**0.42**			
15	**0.54**			

C-3-3) Models I and II need some Initial values in order to make predictions; which of the following initial values, is the best? (Indicate with a "v" in the answer sheet.)

模式I及II需要族群最初的數量來進行預測,下列何項初始族群數據可達到最佳的預測值? (在答案紙上打勾表示)

A) sitter: 289, active rover212

B) sitter: 205, active rover: 295

C) sitter: 523, active rover: 300

D) sitter: 307, active rover: 514

Pearson correlation:
皮爾森相關係數
Pearson correlation is a mathematical function to estimate the correlation between two sets of data (x_1, …, x_n and y_1, …, y_n). Correlation coefficient is calculated as follows:

皮爾森相關係數是一個數學函數，它是用來估計兩組資料的相關性 (x_1,....,x_n and y_1,...,y_n)。此相關係數的計算如下:

lation coefficient 相關係數 = $\frac{\sum_{i=0}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=0}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=0}^{n}(y_i - \bar{y})^2}}$

n = the sample size 樣本數
x_i = the individual sample points for sample x 每個x樣本
y_i = the individual sample points for sample y 每個y樣本
$\bar{x} = \frac{1}{n}\sum_{i=0}^{n} x_i$ $\bar{y} = \frac{1}{n}\sum_{i=0}^{n} x_i$

C-4) Calculate correlation coefficient (r) for the desired correlations and fill in the table below.
計算相關係數(r),並填入下表.

Sample X 樣本X	Observed sitters 觀察到不好動者的頻度 (frequency)	Observed sitters 觀察到不好動者的頻度 (frequency)
Sample Y 樣本Y	Sitters predicted by model I 由模式I預測不好動者的頻度 (frequency)	Sitters predicted by model II 由模式II預測不好動者的頻度 (frequency)
Correlation coefficient 相關係數		

***C-5*)** Indicate each of the following statements is true or false with a "✓" in the answer sheet.
在答案卷上勾選下列敘述的對錯.

A) The logistic model I explains the observed changes in frequencies given the parameters.
A)根據所提供的參數數值，對數(邏輯)模式I可以解釋觀察到的頻度變化.

B) Your calculations show that include competition in our model significantly increased the fit between model and our observation.
B)若將競爭納入模式內計算, 可以顯著增加模式與實際觀察結果的吻合度.

C) We need to explore the parameter space to establish the ability of these models to explain our observation.
C)我們需要探索參數數值可能出現的範圍,使模式能夠解釋實際觀察到的現象.

D) The correlation estimates suggest that the change in the frequencies of sitters and rovers is not due to competition.
D)此相關性分析的結果顯示,不好動與好動者間出現頻度的改變,與競爭無關.

Student Code:

ANSWER SHEET - ECOLOGY AND EVOLUTION答案卷 - 生態學與演化學

A-1) Based on the observed results on plates, fill the table 1 in the answer sheet. (Correct to two digits after decimal point) (8.5 points – 0.2 point for each count and frequency; 0.5 point for each H.)
A-1）根據在培養皿上觀察到的結果，將數據填寫答案卷中的表1。（正確到小數點後的兩位數）（8.5分 - 每個計數和頻率0.2分;每個H 0.5分）

Table 1:

Plate	SM (Count)	WS (Count)	FS (Count)	SM (Freq)	WS (Freq)	FS (Freq)	H
A0							
A7							
B7							
A14							
B14							

A-2) Based on the data obtained, indicate if each of the following statements is true or false with a "✓". (1.5 points)
A-2）根據所得的數據，用"✓"表示以下敘述的對錯。（1.5分）

	True	False
A		
B		
C		

D		
E		

A-3) Assuming that there are only three bacterial morphs, calculate maximum achievable heterogeneity (Correct to two digits after decimal point) (2.5 points).
A-3）假設只有三種細菌菌落形態，計算可達形態異質性的最大值（正確到小數點後的兩位數）（2.5分）。

PART B: (20 points)

B-1) indicate if each of the following statements is true or false with a "✓". (15 points, 3 points each)
B-1）用"✓"表示下列各敘述的對錯。（15分，每個3分）

	True	False
A		
B		
C		
D		
E		

B-2) Indicate which of the following equations about equilibrium heterogeneity best fit with simulation results. Indicate the true choice with a "✓". (5 points)
B-2）以下哪個有關賴特-費雪平衡狀態下的異質性的公式最符合你的模擬結果。用"✓"來選正確者。（5分）

	A	B	C	D	E
Answer:					

PART C: (60 points)

C-1) Using the film from the fruit flies larva, complete the table below (Use the same method as part A to calculate H; Correct to two digits after decimal point; 0.5 point for each count; 0.5 point for each H; 0.2 point for each frequency.) (9.5 points)

C-1）觀察影片中果蠅幼蟲的行為，將結果填入下表（用與A部分相同的方法計算H 至小數點後兩位數;每個計數0.5分;每個H 0.5分; 每個比例0.2分。）（9.5分）

Table 2:

No. of generation	**Sitters (count)**	**Active rovers (count)**	**Sitters (freq)**	**active rovers (freq)**	***H***
1					
2					
3					
4					
5					

C-2) indicate if each of the following statements is true or false with a “✓”. (1.5 points) (6 points)
C-2）用“✓”表示下列敘述的對錯。（1.5分）（6分）

	True	False
A		
B		
C		
D		

C-3-1) Complete the table below based on model I and model II. Parameters of model are as follow (Correct to two digits after decimal point) (0.25 points for each box in model I and 0.75 points for each box in model II) (14 points)
C-3-1) 根據模式 I和模式 II 完成下表。模式參數如下（正確到小數點後兩位）（模式 I中每格 0.25分，模式 II中每格 0.75分）（14分）

	Model I	Model II	Model II
No. of generation	**Sitter (count)**	**Sitter (count)**	**Rover (count)**
0	**184.00**	**184.00**	**262.00**
1			

2	427.79	343.22	408.41
3			
4	196.94	120.45	381.17
5			
6	371.71	539.93	368.38
7			
8	34.89	571.68	459.81
9			
10	424.04	459.64	522.19
11			
12	182.86	516.81	497.54
13			
14	432.68	589.09	510.47
15			

C-3-2) Calculate frequencies of feeding strategies predicted by these two models and fill the table below (For model I, since we have rovers in the population in addition to the sitters, to calculate the frequency of the sitters divide the number of sitter by 2 × K); Correct to two digits after decimal point).

分別根據模式 I與模式II，預測兩種覓食策略出現的頻度，並填入下表(在模式I中，由於除了不好動者外,尚有好動者.故要計算不好動者出現的頻度,需將不好動者的數量除以2K);答案需到小數點後兩位,

Table 4: (each box 0.2 points) (9 points)
表4 :(每格0.2分）（9分）

	Result of our study	Prediction of model I	Prediction of model II	Prediction of model II
No. of generation	Sitter	Sitter	Sitter	Active rover
0	0.41			

1	**0.54**			
2	**0.61**			
3	**0.62**			
4	**0.91**			
5	**0.32**			
6	**0.68**			
7	**0.63**			
8	**0.46**			
9	**0.27**			
10	**0.84**			
11	**0.67**			
12	**0.47**			
13	**0.39**			
14	**0.42**			
15	**0.54**			

C-3-3) Indicate the true choice with a “✓”. (2 points)
C-3-3）用“✓”表示正確的選擇。（2分）

	A	B	C	D
Answer:				

C-4) Calculate correlation coefficient (r) for the desired correlations and fill in the table below. (7.75 points for each)
C-4）就所要的相關項目，計算相關係數（r），並填寫下表。（每個7.75分）

Sample x	Observed sitters (frequency) 觀察到不好動者的頻度	Observed sitters (frequency) 觀察到不好動者的頻度
Sample y	**Sitters predicted by**	**Sitters predicted by model**

	model I (frequency) 由模式I預測不好動者的頻度	II (frequency) 由模式II預測不好動者的頻度
Correlation coefficient 相關係數		

C-5) Indicate each of the following statements is true or false with a “✓” in the answer sheet. (4 points)
C-5）在答案卷上用“✓”勾選下列敘述的對錯。（4分）

	對	錯
A		
B		
C		
D		