注意：考試開始鈴響前，不得翻閱試題，並不得書寫、畫記、作答。

國立清華大學 115 學年度碩士班考試入學試題

系所班組別：生命科學暨醫學院
丁組(醫學生物科技學程)

科目代碼：0702

考試科目：生物學

一作答注意事項一

1. 請核對答案卷（卡）上之准考證號、科目名稱是否正確。
2. 考試開始後，請於作答前先翻閱整份試題，是否有污損或試題印刷不清，得舉手請監試人員處理，但不得要求解釋題意。
3. 考生限在答案卷上標記「由此開始作答」區內作答，且不可書寫姓名、准考證號或與作答無關之其他文字或符號。
4. 答案卷用盡不得要求加頁。
5. 答案卷可用任何書寫工具作答，惟為方便閱卷辨識，請儘量使用藍色或黑色書寫；答案卡限用 2B 鉛筆畫記；如畫記不清（含未依範例畫記）致光學閱讀機無法辨識答案者，其後果一律由考生自行負責。
6. 提早交卷者不可攜出試題，請將試題連同答案卷(卡)交予監考人員，攜出將以違規論處。當節考試結束後試題將置於講台，可自行取回，本試場不負保管責任。
7. 其他應考規則、違規處理及扣分方式，請自行詳閱准考證明上「**國立清華大學試場規則及違規處理辦法**」，無法因本試題封面作答注意事項中未列明而稱未知悉。

國立清華大學 115 學年度碩士班考試入學試題

系所班組別：生命科學暨醫學院甲組、丁組

考試科目（代碼）：生物學(0402、0702)

一、單選題(每題 2 分，共 50 分)

1) During the preparation of scrambled eggs, the heat-induced denaturation of ovalbumin results in a loss of its native biological conformation. Which of the following levels of protein organization remains fundamentally intact throughout this process?
A) Primary structure
B) Secondary structure
C) Tertiary structure
D) Quaternary structure
E) All levels are equally disrupted by thermal agitation.

2) Living organisms increase in complexity as they grow, resulting in a decrease in the entropy of an organism. How does this relate to the second law of thermodynamics?
A) Living organisms do not obey the second law of thermodynamics, which states that the entropy of an organism increases with each energy transformation.
B) As a consequence of the processes required for growth, the decrease in entropy of the organism is associated with a corresponding increase in the entropy of the universe.
C) As a consequence of the processes required for growth, the decrease in entropy of the organism is associated with a corresponding decrease in the entropy of the universe.
D) Living organisms can transform chemical energy into entropy.
E) None of the above.

3) To analyze the dynamic spatio-temporal movements of condensed chromosomes during mitotic anaphase in a living eukaryotic cell, which of the following imaging modalities is most appropriate?
A) Bright-field microscopy of unstained, fixed cells
B) Standard light microscopy using live-cell imaging (e.g., phase-contrast or DIC)
C) Scanning electron microscopy (SEM) of gold-sputtered samples
D) High-resolution transmission electron microscopy (TEM)
E) Atomic force microscopy (AFM) conducted under vacuum conditions

4) Testosterone is a lipophilic steroid hormone that diffuses freely across the plasma membrane of all cells via passive diffusion. Despite this ubiquitous entry, only specific "target cells" exhibit a physiological response. Which statement best explains this specificity?
A) All cells possess the gene for the testosterone receptor, but only target cells have undergone the epigenetic modifications necessary to express the receptor protein.
B) Targeted response is determined by the presence of cell-surface protein channels that actively pump testosterone into the cytoplasm against its concentration gradient.
C) Only target cells possess the membrane-bound G-protein coupled receptors (GPCRs) required to activate the adenylyl cyclase signaling pathway.
D) The high concentration of cytoplasmic proteases in non-target cells degrades testosterone before it can reach the nuclear envelope.
E) Only target cells contain the specific intracellular receptor proteins that, upon ligand binding, translocate to the nucleus to act as transcription factors.

5) Which of the following would be the most effective "poison" for the process of glycolysis specifically?
A) A chemical that removes all oxygen from the cell.
B) A chemical that destroys pyruvate after it has already been made.
C) A "fake" sugar molecule that looks like glucose but cannot be broken down.
D) A chemical that turns all NADH back into NAD^+.
E) A chemical that stops the mitochondria from using oxygen to make ATP.

6) Which of the following best describes the timing of the Calvin cycle (carbon fixation) and cellular respiration in a living plant?
A) Both processes are strictly dependent on direct sunlight and stop at night.
B) The Calvin cycle runs during the day, while respiration is reserved for the night.
C) The Calvin cycle requires the "light-dependent" products of the day, while respiration occurs continuously regardless of light.
D) The Calvin cycle only happens in the dark to conserve water, while respiration only occurs in the light.
E) Respiration occurs only in the roots, while the Calvin cycle occurs only in the leaves.

7) In the life cycle of sexually reproducing eukaryotes, the process of meiosis reduces the chromosomal complement to a haploid state (*n*). Which event is mechanistically responsible for the restoration of the diploid state (*2n*) in the subsequent generation?
A) S-phase DNA replication, which doubles the genetic material within a single cell.
B) The random alignment of bivalents along the metaphase plate during Meiosis I.
C) The physical exchange of genetic material between non-sister chromatids during Prophase I.
D) The syngamy of paternal and maternal gametes to form a totipotent zygote.
E) The degradation of polar bodies following the completion of Meiosis II in oogenesis.

8) During DNA replication, the enzyme primase synthesizes a short RNA fragment to provide a 3'-OH group for DNA Polymerase III. Consider the following DNA template sequence at the replication fork:
3' — C C T A G G C T G C A A T C C — 5'
If an RNA primer begins synthesis using the underlined Cytosine (C) as the first template base and proceeds toward the 5' end of the template, which of the following is the correct primer sequence?
A) 5' — G A C G T T A G G — 3'
B) 3' — G A C G U U A G G — 5'
C) 5' — G A C G U U A G G — 3'
D) 5' — C C U A G G C U G —3'
E) The primer cannot be synthesized in this direction because RNA polymerase only reads from 5' → 3'.

9) A bacterium uses a "repressor" protein to turn a specific gene OFF when it has enough of a particular nutrient. If a mutation destroys the gene that makes this repressor protein, what will happen?
A) The gene will stay OFF forever because there is nothing to turn it on.
B) The gene will stay ON constantly because the "off-switch" protein is missing.
C) The repressor will get stuck to the DNA and never let go.
D) The mRNA will change its shape and keep making proteins forever.
E) The bacterium will stop growing until it can fix its DNA.

10) A researcher synthetically produces a eukaryotic mRNA transcript but omits the 7-methylguanosine (5' cap) and the 3' poly-A tail. If this modified RNA is microinjected into the cytoplasm of a mammalian cell, what is the most probable metabolic fate of the molecule?
A) The mRNA will be sequestered into the nucleolus for post-transcriptional processing.
B) The transcript will be recognized by the eIF4F complex and translated at a basal rate.
C) The mRNA will undergo rapid exonucleolytic cleavage by cellular ribonucleases.
D) The cell will recognize the lack of a tail and initiate "non-stop decay" after the first round of translation.
E) The mRNA will be reverse-transcribed by cellular DNA polymerases to be stored as cDNA in the genome.

11) If a radical nondisjunction event occurs during gametogenesis, resulting in the duplication of the entire chromosomal complement rather than individual loci, what is the most likely genomic outcome for the resulting offspring?
A) Formation of a pseudogene due to the loss of selective pressure on the redundant copy.
B) Development of a gene cluster via unequal crossing over on a single chromosome.
C) Establishment of autopolyploidy, increasing the total number of sets of chromosomes in the organism.
D) Reversion to a diploid state through the immediate loss of all extra chromosomal material.
E) The creation of a haploid individual due to the mechanical failure of the spindle fibers.

12) A scientist makes a "hybrid" virus: it has the "skin" (protein) of Virus A but the "brains" (DNA) of Virus B. After it infects a cell and makes babies, what will the baby viruses look like?
A) They will look like the hybrid parent (A skin, B brains).
B) They will be 100% Virus B (B skin and B brains).
C) They will be 100% Virus A (A skin and A brains).
D) They will be a random mix of both.
E) No babies will be made because the parts don't match.

13) The diversification of the wild mustard (*Brassica oleracea*) into distinct cultivars such as broccoli, kale, and Brussels sprouts is a classic example of intensive artificial selection. Which statement best explains the biological basis for this successful radiation?

A) The wild mustard genome contains significant heritable variation (standing genetic variation), providing the raw material for selective breeding.

B) Selective breeding induces new targeted mutations in the mustard genome to create desired shapes like florets or large leaves.

C) The high phenotypic plasticity of Brassica allows environmental factors, such as soil nitrogen, to be permanently encoded into the germline.

D) Wild mustard populations lack natural selection pressures, which allowed deleterious mutations to accumulate and create these varieties.

E) The different varieties are actually the result of horizontal gene transfer from unrelated vegetable species in the same habitat.

14) A group of mammalogists has constructed a phylogenetic tree for a specific clade based on morphological synapomorphies (bone structure). If a second phylogeny were constructed for the same taxa using the amino acid sequence of a highly conserved metabolic enzyme, what would be the most scientifically sound expectation?

A) The molecular phylogeny will likely contradict the morphological tree because proteins evolve through different mechanisms than skeletal structures.

B) The phylogenies will be largely concordant (similar), as both reflect the same underlying evolutionary history of the lineage.

C) No correlation can be expected because the rate of mutation in metabolic enzymes is independent of the rate of morphological change.

D) The enzyme sequence will be identical across all taxa because it is "highly conserved," providing no phylogenetic signal.

E) The molecular tree will be fundamentally more accurate because morphological traits are always the result of convergent evolution.

15) A small group of dark-eyed juncos was geographically isolated from their ancestral mountain population and established a new colony on the California coast. Genetic analysis shows that coastal males have significantly less white in their tail feathers (36%) than the ancestral group (45%). If this difference appeared immediately upon the establishment of the new colony, what is the most likely cause?
A) A high rate of de novo mutations occurring after the move to the coast.
B) Gene flow between the mountain and coastal populations increasing tail diversity.
C) A bottleneck effect caused by a sudden environmental disaster on the coast.
D) A founder effect, where the small initial group of birds possessed less white in their tails than the average of the source population.
E) Sexual selection by coastal females shifted the trait toward less white in less than one generation.

16) The common edible frog (*Rana esculenta*) is a hybrid resulting from the cross between *Rana lessonae* and *Rana ridibunda.* While these hybrids are widely distributed and physically robust, they exhibit "hybrid breakdown" or sterility when mating with other hybrids. Which of the following is the most accurate conclusion regarding the evolutionary relationship between the two parent species?
A) They are distinct species maintained by postzygotic isolation, as the hybrid offspring fail to produce a viable F_2 generation.
B) They are the same species because the production of a widely distributed F_1 generation proves a lack of reproductive barriers.
C) They are separated by prezygotic isolation, preventing the initial formation of zygotes in the wild.
D) The hybrids represent a new species under the Biological Species Concept because they can survive across diverse climates.
E) The two species are undergoing "reinforcement," where hybrid sterility eventually leads to the evolution of better mating calls to prevent hybridization.

17) The formation of xylem tension **is not** influenced by which of the following factors or components?
A) Transpiration
B) Water's cohesion
C) Water's adhesion
D) Root uptake of water
E) None of the above

18) Which of the following descriptions about mosses **is not** correct?
A) They are non-vascular plant species.
B) They belong to Bryophyta.
C) They grow in moist and shady places.
D) They absorb water and nutrients through true roots.
E) They exhibit a life cycle involving distinct gametophyte and sporophyte stages.

19) Which of the following descriptions about trichomes is not correct?
A) They are hair-like structures on plant surfaces.
B) They serve diverse roles, like defense against pests and reducing water loss
C) Certain trichomes create essential oils, resins, and medicinal compounds
D) They can reflect UV light
E) They are specialized outgrowths of the cortex cells.

20) Which of the following descriptions about parasitic plants **is not** correct?
A) They utilize a specialized organ called a haustorium to penetrate the host's tissues and establish a vascular connection.
B) They can be classified as photosynthate-active or photosynthate-limited, depending on whether they rely on photosynthate or a host for carbon.
C) They do not synchronize their lifecycle with their hosts.
D) Host defense mechanisms also play a crucial role in determining the success of parasitic plants.
E) Climbers and epiphytes are not parasitic plants.

21) Which of the following structures is unique to cardiac muscle cells?
A) Sarcomere
B) Sarcoplasmic reticulum
C) Intercalated discs
D) Formation of actin/myosin crossbridge in the presence of Ca^{2+}
E) Gap junctions

22) The nervous system and endocrine system are both essential for the coordination and control of the body. Which of the following statements is **NOT** true?
A) Both systems act on specific target cells, although the mechanisms differ.
B) Both respond to internal and external stimuli.
C) Both can influence each other's function.
D) Both have long-lasting effects.
E) Both systems rely exclusively on chemical signals to communicate.

23) Which of the following hormones exhibits both positive and negative feedback controls on hormone release from the hypothalamus?
A) Follicle-stimulating hormone (FSH)
B) Luteinizing hormone (LH)
C) Estradiol
D) Progesterone
E) Testosterone

24) In the homeostatic regulation of mammalian acid-base balance, central and peripheral monitors detect fluctuations in the partial pressure of CO_2 and the concentration of H^+ ions. Which of the following best categorizes the specialized sensory receptors located in the carotid bodies and the medulla oblongata responsible for this task?
A) Baroreceptors
B) Nociceptors
C) Thermoreceptors
D) Chemoreceptors
E) Proprioceptors

25) Which of the following experimental designs would provide the most robust evidence for the hypothesis that high-intensity ultrasound from bats serves as a specific trigger to inhibit moth flight?
A) Electrophysiological recording of moth motor neurons while mechanically stimulating the wing muscles.
B) Field observation of wild moths using high-speed infrared cameras while broadcasting ultrasonic pulses at frequencies and decibels mimicking hunting bats.
C) Qualitative observation of bat-moth interactions in a cave system to determine the percentage of successful strikes.
D) Laboratory trials comparing moth flight patterns when exposed to three-dimensional physical models of predators versus non-predatory insects.
E) Statistical analysis of moth population densities in regions with varying bat activity to correlate survival with flight cessation habits.

二、簡答題（第 1 題每題 6 分；第 2~12 題每題 4 分，共 50 分）

1) The primary challenge in oncological pharmacology is achieving site-specific delivery while minimizing systemic toxicity. You are tasked with designing a drug delivery vehicle for a novel lung cancer therapeutic that must bypass the systemic circulation and selectively enter the cytoplasm of malignant lung epithelial cells. Discuss the molecular mechanisms you would exploit to ensure this specificity. In your response, compare the efficacy of targeting the extracellular matrix (ECM) with that of receptor-mediated endocytosis. Why is the mere chemical property of the drug (such as hydrophobicity) insufficient for achieving high tissue specificity in a complex multicellular organism?

2) In an experimental dataset, researchers often encounter 'outliers'—data points that deviate significantly from the established trend or theoretical expectation. Critically evaluate the scientific and ethical implications of data exclusion. Specifically, discuss why the practice of omitting outliers without transparent justification (as suggested in options A and B of the original multiple-choice prompt) undermines the validity of research. In your response, address how a researcher should systematically investigate these anomalies and what their presence might reveal about the experimental design or the phenomenon under study.

3) Tumorigenesis is traditionally viewed as a disorder of excessive cellular proliferation. However, modern oncology recognizes that the accumulation of cell mass is equally dependent on the evasion of programmed cell death. Critically analyze the role of apoptosis (programmed cell death) in maintaining tissue homeostasis. Explain how a defect in the apoptotic pathway can lead to tumor formation even if the rate of cell division remains normal. In your response, provide one example of a molecular 'checkpoint' or protein (such as p53 or the Bcl-2 family) that regulates this balance.

4) Mendel's F_2 data (6,022 yellow: 2,001 green) is often cited as a cornerstone of classical genetics.
a) Calculate the phenotypic ratio and explain how this specific mathematical outcome supports the Law of Segregation.
b) If the yellow F_1 plants had been 'test-crossed' with the original true-breeding green parents instead of self-pollinated, what phenotypic ratio would you expect in the resulting offspring? Justify your answer

5) The genetic code is described as being 'nearly universal' across all three domains of life. Critically evaluate the evolutionary and biotechnological implications of this universality.
a) Explain how the conservation of the genetic code provides evidence for a Last Universal Common Ancestor (LUCA).
b) Discuss how this principle allows for the production of human proteins (such as insulin) in prokaryotic systems like *E. coli.*

6) Explain the relationship between concentration and electrical charge in a living cell. If you increase the amount of Potassium inside a cell, why does the cell end up with a more negative electrical charge?

7) The nematode *C. elegans* is considered a 'Model Organism.' Explain what this term means. Why does studying the DNA of a simple worm help us understand complex human diseases like cancer or Alzheimer's?

8) The development of mRNA vaccines represents a paradigm shift in vaccinology, moving from the delivery of exogenous antigens to the delivery of genetic instructions. Critically evaluate the role of the Lipid Nanoparticle (LNP) and the host ribosome in the efficacy of an mRNA vaccine. Explain why the mRNA must be chemically modified (e.g., using pseudouridine) to bypass the host's innate immune sensors. Finally, describe the intracellular pathway by which the resulting protein is presented on the cell surface via MHC class I molecules.

9) Explain how a 'position effect' can cause cancer. Specifically, describe what happens when a growth-regulating gene (a proto-oncogene) is moved to a new location on a different chromosome. Why does this result in a tumor?

10) Please give an example of C4 plants and elaborate on why C4 plants have an advantage in water conservation.

11) Explain the pathway involved in the acute (short-term) stress response, including:
a) the gland involved
b) the hormones released
c) the target tissues affected
d) the physiological effects of these hormones

12) Explain how the human kidney concentrates urine through the two-solute system, including:
a) define what is the two-solute system
b) key structure involved
c) mechanism of concentration
d) physiological effects