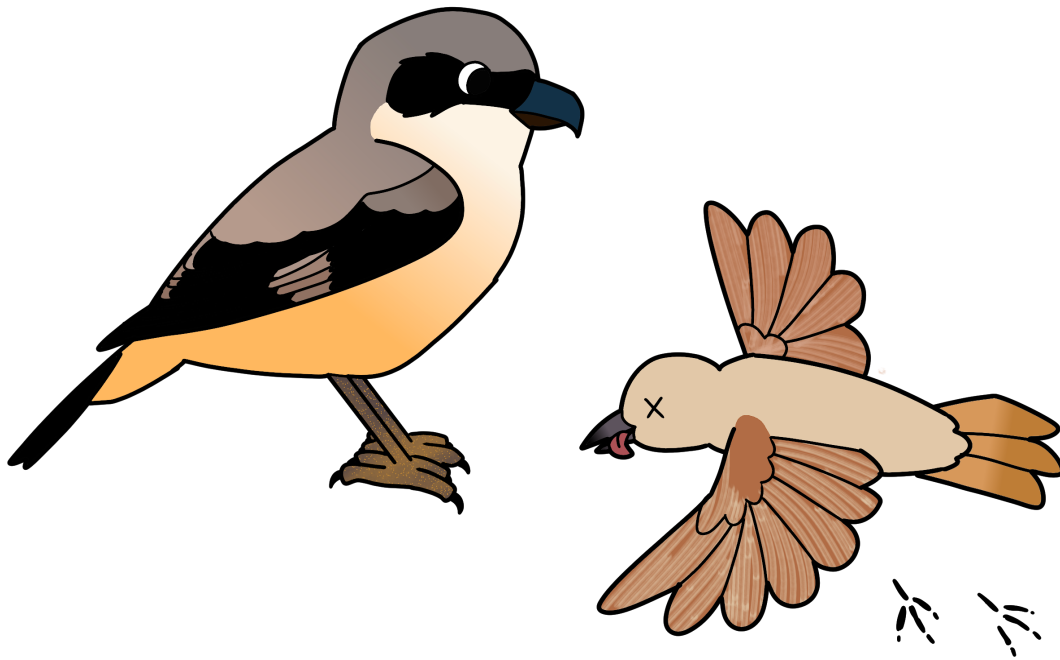


2021 BirdSO Invitational



Forensics

Answer Key

Total Score: 529/529

Rank: 0

This test was written by Camille Zhang (Mira Loma '20 and Brown '24) and
Zoe Goldblum (Cumberland Valley '20 and Penn State '24)

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Instructions:

- As this is an online tournament, there will be no wet lab component to this exam.
- You will have **50 minutes** to complete your exam. At the end of this time period, your test will be automatically submitted through Scilympiad. Partial credit will be awarded, so attempt as many questions as you can! Don't worry if you don't finish! This test is intended to be long--just try your best and move on if you get stuck on a question. You can always come back to it!
- Each participant is allowed **2** note sheets with information on both sides, but as per tournament rules, they must be printed out.
- When specifying evidence in the Analysis of the Crime, please use the evidence name, not the number (e.x. Say "NaCl" or "Sodium Chloride" rather than "Powder 1." **No credit will be given to teams who do not explicitly state the names of the pieces of physical evidence.**
- Ties will be broken in accordance with the national Science Olympiad rules in this order:
 - ◆ Written Analysis of the Crime
 - ◆ Powders
 - ◆ Hairs
- You may voice call or video call your partner through any platform (Zoom, Discord, Messenger, etc.)
- Your time outside of the test **WILL** be monitored, so make sure to stay inside of the browser.
- You will not be required to submit any work. However, we recommend you have a piece of scrap paper and a writing utensil with you while you're taking this test.
- Please fill out the following Google form (after the exam period, of course) to give me (Zoe) some feedback on the test! <https://forms.gle/oYbACwKK8623oPYB8>

CASE DESCRIPTION:

In Rio de Janeiro, Blu and Jewel have been kidnapped again! Their previous owners, Linda and Túlio, have been visiting them in the jungle every day since they were released, but one day noticed that they were missing! They are absolutely devastated that their bird friends have been stolen! On their way to the local police station, Túlio receives a phone call. The line is full of static and the voice is difficult to make out. However, the message is clear: Túlio must pay a ransom of \$30,721 in the next 48 hours or Blu and Jewel will be killed. After speaking to the police, Túlio and Linda are able to narrow it down to six potential suspects: Eric Ma, Allen Chang, Jason Chang, Gwennie Liu, Andrew Zhang, and Crystal Zhu. All six of these individuals have been in the section of the Amazon Rainforest where Blu and Jewel live in the timeframe in which they were stolen. Their interviews and character backgrounds are listed on the following pages. Utilize this evidence along with the knowledge you have acquired in your time as a Forensic Scientist at BirdSO Forensic Laboratories to help save Blu and Jewel!



You begin your investigation by speaking to the head of tourism at Blu and Jewel's corner of the Amazon. They tell you that everyone must sign in and out before they can enter, as many endangered species are housed here. You ask for this sign-in sheet, and they are happy to give it to you! This table is attached below:

Name	Date	Time In	Time Out
Eric Ma	3/6/21	10:07 AM	11:33 AM
Andrew Zhang	03-06-2021	12:00 PM	12:45 PM
Jason + allen chang	3-6-21	1:05 PM	3:30 PM
C. Zhu	3/6/2021	2:14 PM	3:17 PM
Eric Ma	3/6/21	3:45 PM	5:38 PM
Gwennie Liu	3-6-2021	3:50 PM	5:25 PM

Disclaimer: Not everything said about the suspects is true. In fact, most of it isn't. But that is irrelevant. The truth matters not. What matters now is that you have 50 minutes to solve a fake crime better than the other fake crime solvers to try to get a shiny metal disk. Now get going, you funky little crime solvers.

SUSPECT DESCRIPTIONS:

Eric Ma

Personal Statement: “My name is Eric Ma, and I am a freshman at UCLA studying electrical engineering. In my free time, you can catch me playing some instrument, taking photos of the sidewalk, and napping to avoid my homework.”

Investigator’s Notes: When we went to visit and investigate Eric, he was asleep. Luckily, we had a chance to speak with his mother, who was annoyed with him since he naps too much. Because of this, he doesn’t have time to get a part-time job to help pay off his student loans, as UCLA is very expensive for their family. Once Eric woke up, he was eating a bag of salt and vinegar chips and drinking a soda (Caffeine: $C_8H_{10}N_4O_2$) as he attempted to complete a physics problem set before a deadline. On the day of the crime, Eric was wearing Denim jeans and a nylon shirt. Eric is 5’6, has type O+ blood, and a double loop whorl fingerprint. He writes with a Ballpoint pen.

Allen Chang

Personal Statement: “Hi, I’m Allen Chang, a junior from West Windsor-Plainsboro High School North (‘22). I have a lot of experience in building, and my hobbies include programming and indoor free flight, and my favorite pen is the Pentel EnerGel Deluxe Gel Pen.”

Investigator’s Notes: Allen and his twin brother, Jason, went into the rainforest together to test out a model bird that they built together. Allen loves indoor free flight(which uses a lot of rubber ($(C_5H_8)_n$), and wants to be able to build something that can really fly. Since the rainforest has so many unique and wonderful birds, he often visits to find inspiration. On the day of the crime, Allen was wearing spandex underwear and a polyester shirt. Allen is 5’9, has Type A- blood, and an ulnar loop fingerprint.

Jason Chang

Personal Statement: “Hey! I’m Jason Chang, a junior from West Windsor-Plainsboro High School North in Plainsboro, New Jersey (‘22). Since 6th grade, I have loved engineering. I’m a 3D printing enthusiast.”

Investigator’s Notes: Jason corroborates Allen’s story that the two of them went into the Amazon Rainforest to fly the model bird they had built together. Even though Jason prefers building model cars and vehicles, he was happy to help his brother out by 3D printing pieces for Allen’s model bird (3D printing filament: $((C_3H_4O_2)_n)$). However, neither brother is an experienced ornithologist, and they have visited the rainforest quite a lot recently to study the mechanics of bird flight. One the day of the crime, he was wearing silk underwear and a nylon shirt. We asked both brothers to show us the clothes they wore that day, and suspiciously, both of their underwear had holes in the back. They looked embarrassed and claimed it was because they had accidentally gotten too close to a bird’s nest and got attacked by a protective mother parrot who thought they would steal her babies, so they had some cuts on their arms and legs. Jason is 5’8, also has Type A- blood, and a plain arch fingerprint. Jason writes with a Muji pen.

Gwennie Liu

Personal Statement: “Heyo! My name is Gwennie Liu and I’m a junior at Torrey Pines High School in San Diego, California. My favorite things to study include Astronomy and Geology. In my free time, I enjoy binging dramas and knitting.”

Investigator’s Notes: When we had arrived at Gwennie’s house to interview her, she was visibly upset, and we also noticed there was a bandage on her arm. After some further investigation, we learned that she and her parents had gotten into a fight. Gwennie keeps refusing to get a job, since that would cut into her time for knitting and binge-watching dramas. Her parents believe she is wasting her time and their money and want her to get a part-time job to pay for her own knitting equipment, but Gwennie keeps refusing. Gwennie says she was in the Rainforest because one of her favorite dramas took place there and wanted to see it for herself. Gwennie is 5’1, has type AB+ blood, and a radial loop fingerprint. On the day of the crime, she was wearing a polyester t-shirt and denim jeans. She writes with a Magic Marker.

Andrew Zhang

Personal Statement: “Hello my name is Andrew Zhang! I’m a senior (c/o 21) at Syosset High School in New York. My favorite thing to study is Astronomy, but I’ve also enjoyed studying Fossils, Material Science, and Invasive Species. In my free time I spend too long playing cryptograms.”

Investigator’s Notes: When we arrived at Andrew’s house to interview him, he had just returned from going on a walk in a different part of the rainforest. We asked him about his walking habits, and he explained that his doctor had recently diagnosed him with both heartburn and bipolar disorder. On top of all of this new medication, his doctor recommended that he went for a 30-45 minute walk everyday to get some much needed sunlight and fresh air. He talked about his bipolar disorder further, and said it has gotten worse lately after being put under some serious financial stress. More importantly, his parents think that there is no future in just solving cryptograms, which is one of the few things he truly enjoys, so they started making him pay for himself until he starts doing more useful things. Despite his doctor’s guidance, Andrew still loves eating chocolate ($C_7H_8N_4O_2$) when his parents are away. On the day of the crime, he was wearing denim jeans and a cotton shirt. Andrew is 5’11, has type B+ blood, and an accidental whorl fingerprint. He writes with a ballpoint pen.

Crystal Zhu

Personal Statement: “Hey there! I’m Crystal Zhu, a senior at Mission San Jose High School in Fremont, California (‘21). I love Ornithology, as I am a huge bird nerd. In my free time, I love birdwatching and drawing.”

Investigator’s Notes: Crystal loves birds so much that she wants to go to school to become an ornithologist. Additionally, she dreams of one day owning birds of her own, but unfortunately her parents will not let her. Because she can’t own birds of her own, she often goes into the rainforest to admire and study them. Unfortunately, Crystal is quite scared of bugs, and since the Amazon Rainforest has so many, she needs to use a lot of insecticide to feel safer. We didn’t get much out of Crystal, so we decided to interview her younger sister as well. Her sister said that she overheard Crystal telling friends she loves rare birds so much she wishes she could take them home and watch them at her house 24/7. On the day of the crime, she was wearing denim jeans and a wool sweater. Crystal is 5’2, has type O- blood, and a central pocket whorl fingerprint. She writes with a Sharpie.

Section A: Powders [83 pts]

Powder	Solubility in Distilled Water	Reaction with HCl	pH	Reaction with NaOH	Benedict's test	Flame test
A	soluble	none	6	none	turns dark blue	faint green
B	soluble	none	8	none	none	yellow
C	soluble	none	6	white precipitate	none	doesn't melt (glows)
D	soluble	fizzes	12	insoluble	none	yellow
E	soluble	none	4	none	none	green
F	soluble	none	6	none	none	melts
G	soluble	none	7	none	none	red
H	soluble	none	6	none	turns orange	melts
I	insoluble	fizzes	9	insoluble	none	reddish orange
J	soluble	none	6	white precipitate	none	reddish orange
K	soluble	none	8	none	none	yellow
L	soluble	none	7	none	none	violet

Identify the following powders (and their formulas) and state at least one general use, as well as another use that connects to the crime scene:

1) Powder A + uses: [4]

Ammonium chloride, NH_4Cl ; textile and leather industry, medical treatment; fertilizers

2) Who does this powder incriminate, if anyone? [1]

No one

3) Powder B + uses: [4]

Sodium acetate, $\text{NaC}_2\text{H}_3\text{O}_2$; heating packs; salt and vinegar chips

Forensics Key

4) Who does this powder incriminate, if anyone? [1]

Eric

5) Powder C + uses: [4]

Magnesium sulfate, MgSO_4 ; heat packs, epsom/bath salts; fertilizers

6) Who does this powder incriminate, if anyone? [1]

No one

7) Powder D + uses: [4]

Sodium carbonate, Na_2CO_3 ; cleaning agent, manufacturing glass; photography

8) Who does this powder incriminate, if anyone? [1]

Eric

9) Powder E + uses: [4]

Boric acid, H_3BO_3 ; mild antiseptic, eyewash; insecticides

10) Who does this powder incriminate, if anyone? [1]

Crystal

11) Powder F + uses: [4]

Sucrose, $\text{C}_{12}\text{H}_{22}\text{O}_{11}$; sweetener, baking; soda

12) Who does this powder incriminate, if anyone? [1]

Eric (0.5 points if only wrote Andrew)

13) Powder G + uses: [4]

Lithium chloride, LiCl ; desiccant; bipolar disorder treatment

14) Who does this powder incriminate, if anyone? [1]

Andrew

15) Powder H + uses: [4]

Forensics Key

Glucose, $C_6H_{12}O_6$; baking; soda

16) Who does this powder incriminate, if anyone? [1]

Eric (0.5 points if only wrote Andrew)

17) Powder I + uses: [4]

Calcium carbonate, $CaCO_3$; chalk, construction industry; antacid (relieves heartburn)

18) Who does this powder incriminate, if anyone? [1]

Andrew

19) Powder J + uses: [4]

Calcium nitrate, $Ca(NO_3)_2$; regenerable cold packs; fertilizers

20) Who does this powder incriminate, if anyone? [1]

No one

21) Powder K + uses: [4]

Sodium acetate, $NaC_2H_3O_2$; de-icer; photography

22) Who does this powder incriminate, if anyone? [1]

Eric

23) Powder L + uses: [4]

Potassium chloride, KCl ; high blood pressure treatment, lethal injection; fertilizers

24) Who does this powder incriminate, if anyone? [1]

No one

The following questions are unrelated to the crime scene:

25) Benedict's test is used to differentiate between different types of sugars. What type of sugar (or what property of the sugar) does Benedict's reagent detect? [2]

Accept: reducing sugars, aldehydes, alpha-hydroxy-ketones

26) Depending on the concentration of the powder that yields a positive Benedict's test, the color change will be different. List each of the concentrations that correspond to the following colors: green, yellow, orange, red/brown. [4]

Green: 0.5%, yellow: 1%, orange: 1.5%, red/brown: 2% or more

27) Fill in the following blanks with the appropriate chemical name AND formula:
1L of Benedict's solution is prepared from 100g of anhydrous ____, 173g of ____, and 17.3g of ____ pentahydrate. [6]

Sodium carbonate (Na_2CO_3), sodium citrate ($\text{Na}_3\text{C}_6\text{H}_5\text{O}_7$), copper (II) sulfate (CuSO_4)

28) Benedict's solution will turn dark blue when it is added to a certain powder. List the chemical formula of the powder, as well as the chemical formula (and name) of the ion responsible for the royal blue color. [3]

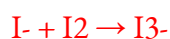
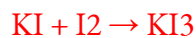
NH_4Cl , tetraamine copper (II) ion: $[\text{Cu}(\text{NH}_3)_4]^{2+}$

29) List the test and the powders that would be affected by using cobalt blue glass and explain why. [4]

Flame test, LiCl and KCl ; cobalt blue glass would filter out/absorb the yellow light emitted by sodium contamination in those powders.

30) Lugol's iodine (which is used in iodine testing) is not pure iodine. Explain why pure iodine cannot be used, and then write the full chemical equation as well as the net ionic equation for making Lugol's iodine. [4]

Pure iodine is a crystalline solid that will slowly sublime at room temperature.



Section B: Polymers [44 pts]

Density test:

Plastic	Water	46% Isopropyl Alcohol	Vegetable Oil	10% NaCl	25% NaCl	Saturated NaCl
A*	sinks	sinks	sinks	sinks	sinks	sinks
B	floats	floats	floats	floats	floats	floats
C	sinks	sinks	sinks	sinks	sinks	floats

*Plastic A has an orange flame test

Identify the following plastics (both the abbreviations and the full names) and state at least one general use, as well as another use that connects to the crime scene:

31) Plastic A + uses: [4]

PETE, polyethylene terephthalate; peanut butter containers; soda bottles

32) Who does this incriminate, if anyone? [1]

Eric

33) Plastic B + uses: [4]

PP, polypropylene; yogurt and butter containers; chip bags

34) Who does this incriminate, if anyone? [1]

Eric

35) Plastic C + uses: [4]

PC, polycarbonate; electrical telecommunications hardware, safety goggles; used for model bird

36) Who does this incriminate, if anyone? [1]

Allen and Jason

The following questions are unrelated to the crime scene:

- 37) What is the more common name for the Beilstein test? Which plastic (give both the abbreviation and full name) burns green in this test and why? [5]

Copper wire flame test; PVC, polyvinyl chloride; the chlorine in PVC will react with the copper in the wire to form CuCl_2 (which burns green)

- 38) Briefly describe the difference between thermoplastics and thermosets. [3]

Thermoplastics can be remolded after it's heated, while thermosets cannot.

- 39) (True/False) All of the plastics listed in the Forensics rulebook are thermoplastics. [1]

- 40) Two of the many types of polymerization include addition and condensation. These can then be generalized into two broader categories of polymerization. Identify them, and explain the difference between them. [7]

Addition is a form of CGP (chain growth polymerization), condensation is a form of SGP (step growth polymerization)

The difference between CGP and SGP is that in CGP, only monomers can be added to the active site of the chain, and it has a very distinct initiation and propagation step, while in SGP, large quantities of monomers are consumed at the beginning of the reaction, and all molecules (monomers, oligomers, and polymers) can react with each other with no clear termination step.

- 41) Give the specific types of polymerization (so NOT the answers to the previous question) of each of the following plastics: PETE, HDPE, LDPE, PVC, PP, PS, PC, PMMA [8]

PETE: condensation/esterification; HDPE, LDPE, PVC: addition; PP: Ziegler-Natta; PS, PMMA: free radical vinyl; PC: condensation

- 42) Explain why LDPE has a lower density than HDPE and why HDPE has a higher tensile strength than LDPE. [5]

LDPE is branched, so the same mass of LDPE will occupy a larger volume, resulting in a lower density. HDPE is linear, so it has tighter packing and stronger intermolecular forces, which results in a higher tensile strength.

Section C: Fibers [35 pts]

Fiber	Burn Test Descriptions
A	Ignites and burns quickly, smells like burnt paper, glowing ember after flame is extinguished, white ash residue
B	Shrinks from flame, hard bead residue, sweet odor, black smoke
C	Shrinks from flame, melts into a hard bead, smells like burnt celery
D	Bright flame, melts, has chemical odor
E	Self-extinguishing, shrivels, smells like burning hair, leaves crushable black bead
F	Shrivels, burns slowly, smells like burning hair, very little smoke, dark brittle ash residue

Identify the following fibers and describe their cross section, as well as how it connects to the crime scene:

43) Fiber A + cross section + connection to crime scene: [3]

Cotton; kidney shaped/elliptical cross section; denim jeans and cotton shirt

44) Who does this implicate, if anyone? [1]

Eric, Gwennie, Andrew, Crystal

45) Fiber B + cross section + connection to crime scene: [3]

Polyester; circular cross section; polyester shirt

46) Who does this implicate, if anyone? [1]

Allen, Gwennie

47) Fiber C + cross section + connection to crime scene: [3]

Nylon; circular or trilobal or irregular cross section; nylon shirt

48) Who does this implicate, if anyone? [1]

Eric, Jason

49) Fiber D + cross section + connection to crime scene: [3]

Spandex; dog-bone cross section; spandex underwear

50) Who does this implicate, if anyone? [1]

Allen

51) Fiber E + cross section + connection to crime scene: [3]

Silk; triangular cross section; silk underwear

52) Who does this implicate, if anyone? [1]

Jason

53) Fiber F + cross section + connection to crime scene: [3]

Wool; cylindrical cross section; wool sweater

54) Who does this implicate, if anyone? [1]

Crystal

The following questions are unrelated to the crime scene:

55) Identify which fibers listed in the Forensics rulebook are plant, animal, or synthetic fibers. If they are plant fibers, specify which part of the plant they are from. [9]

Plant: cotton (seed fiber), linen (bast fiber: from the phloem in the stem)

Animal: silk, wool

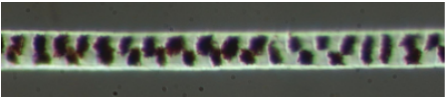
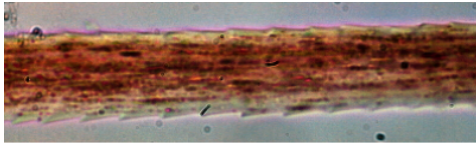
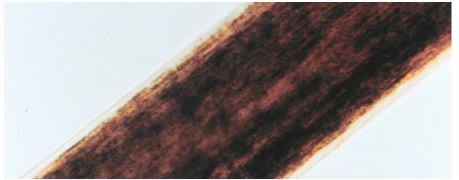
Synthetic: polyester, nylon, spandex

56) Why does burning animal fibers give a pungent odor? [2]

Animal fibers are made from protein (keratin), which has sulfur in it.

Section D: Hairs [36 pts]

Identify the following hair samples by their microscopic images.

Hair A	Hair B	Hair C
		

- 57) Identify Hair A: [3] **Squirrel Hair**
- 58) Who does Hair A incriminate? [1] **None**
- 59) Identify Hair B: [3] **Bat Hair**
- 60) Who does Hair B incriminate? [1] **None**
- 61) Identify Hair C: [3] **Human Hair**
- 62) Who does Hair C incriminate? [1] **All**

The following questions are unrelated to the crime scene:

- 63) With some notable exceptions, the human body is essentially covered with hair. Because of this, Forensic Scientists often find hair samples from numerous different places on the body at a given crime scene. Which part(s) of the body has hair that contains the most information for microscopic comparisons? Select all that apply. [1]
- a) **Head**
 - b) Limbs
 - c) Pubic
 - d) Chest
 - e) **Facial**
 - f) Axial (armpit)
- 64) What are the layers of hair from the outermost to the innermost layer? [3]

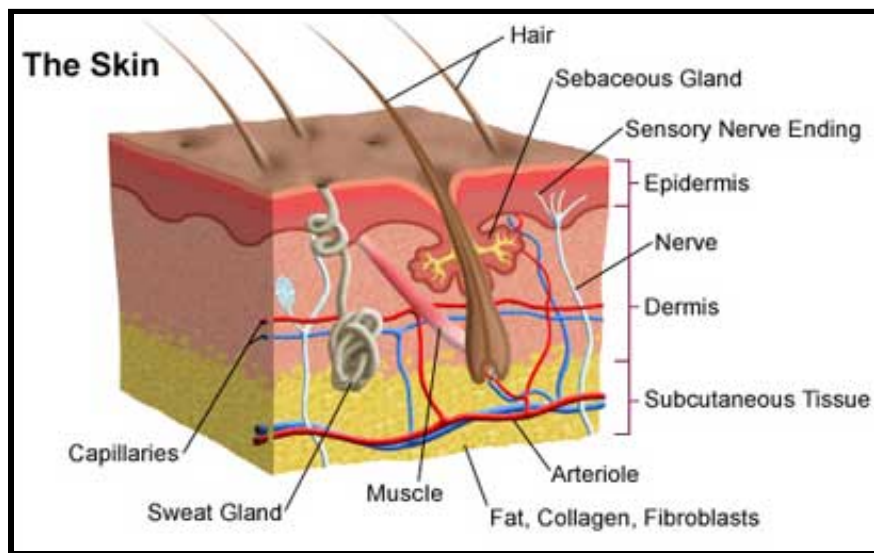
Cuticle, Cortex, Medulla

- 65) Unfortunately for Forensic Scientists, hair is very easily damaged. List two common ways that hair can be damaged. [2]

Dyeing, Bleaching, Breaking, Burning, Putrefied roots, Insect marks, Cutting, Crushing (need 2)

- 66) True or **False**? Hairs from different areas of the body (e.x. Head hair and Axial hair) are comparable under a microscope. [1]

- 67) While all we see is hair above the surface of our skin, the mechanisms to hair growth are actually quite complex! Using this knowledge, label the diagram below. [6]



- 68) Hair cells are some of the fastest replicating cells in the human body. In fact, hair growth averages 6-10 inches per year! List and describe the 3 stages of the hair growth cycle. [3]

Anagen: The active phase of the hair. The cells in the root of the hair are dividing rapidly. A new hair is formed and pushes the club hair up the follicle and eventually out. Lasts 2-6 years.

Catagen: A transitional stage that lasts for about two to three weeks. Growth stops and the outer root sheath shrinks and attaches to the root of the hair. This is the formation of a club hair.

Telogen: The resting phase that lasts for about 100 days for hairs on the scalp and longer for hairs on the eyebrow, eyelash, arm, and leg. During this phase, the hair follicle is completely at rest and the club hair is completely formed.

- 69) Despite what you may have seen on past Science Olympiad tests, Forensic Scientists actually need upwards of 50 individual hair samples from a suspect's head to compare to samples found at a crime scene! Why is this? [2]

This is largely due to inconsistencies that occur in each body region. More specifically, different hairs from one location on a person can vary. Not all hairs on someone's head are exactly the same. For example, a suspect may have a few gray hairs among brown hairs in a sample taken from their head.

- 70) **True** or False? Hair Analysts can tell approximately when a hair sample was last dyed if the entire hair sample is recovered. [1]

- 71) Forensic Scientists rely on the idea that at every crime scene there will be a transfer of materials. What is this called? [1]

Locard's Exchange Principle

- 72) Why are hairs such a good tool in Forensic Science? [1]

Humans naturally shed a lot of hairs per day. Additionally, hair is very well preserved over time.

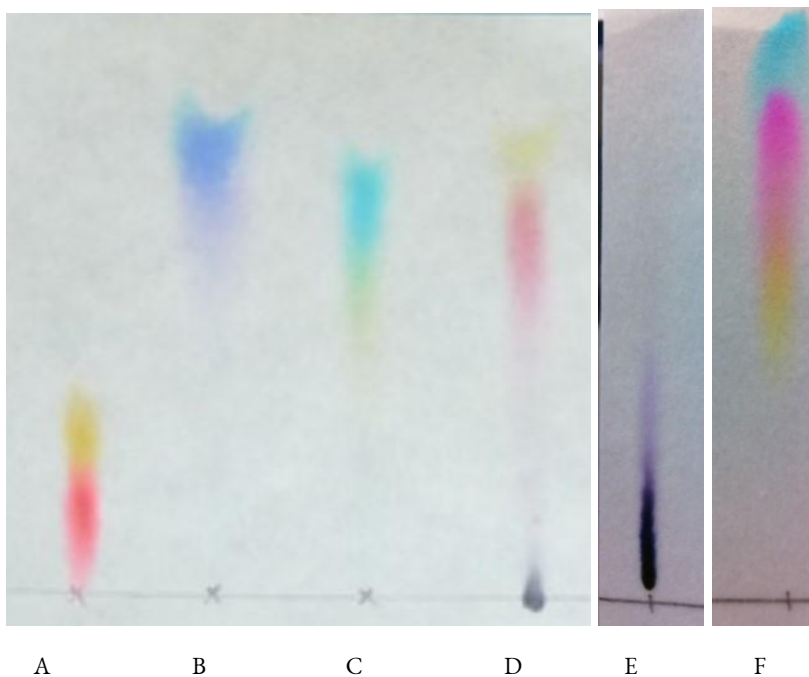
- 73) In the more recent years, Forensic Scientists have been using a technique called Nuclear DNA Analysis to help study hairs. List one advantage and one drawback to performing this procedure. [2]

Advantage: Highly specific; can be used on any type of biological material except blood.

Disadvantage: Not good at analyzing a large volume of genetic material.

Section E: Chromatography [31 pts]

Paper Chromatography was done on the pens collected from the suspects, and TLC was done on the markers.



(use the labels A,B,C,D,E and F when answering the following questions)

74) Match each of the given R_f values for each suspect to the pictures shown above, also give the type of pen/marker they were using according to the suspect descriptions: [12]

Eric: 0.7, 0.8

Allen: 0.6, 0.75

Jason: 0.2, 0.3

Gwennie: 0.6, 0.9, 1

Andrew: 0.7, 0.8

Crystal: 0.4

Eric: B or D, ballpoint pen; Allen: C, gel pen; Jason: A, muji pen

Gwennie: F, magic marker; Andrew: B or D, ballpoint pen; Crystal: E, sharpie

75) Paper chromatography was done on the note that was found on the crime scene. If the pen was found to be a ballpoint pen, who does this implicate? [1] **Eric or Andrew**

76) Thin layer chromatography was done on the ransom note. If the marker was found to be a magic marker, who does this implicate? [1] **Gwennie**

77) Why was TLC used on the sharpie and magic marker instead of paper chromatography? [6]
Paper chromatography uses a polar solvent (mobile phase), which will not work on nonpolar inks like sharpie or other permanent markers. Meanwhile, TLC uses nonpolar solvents, which will result in adsorption to the ink and allow it to move up the plate.

The following questions are unrelated to the Crime Scene:

78) When performing liquid chromatography on an unknown compound, you decide to run two trials: one using water as the mobile phase, and one using ethanol. For the water trial, the compound has an R_f value of .72. For the ethanol trial, the compound has an R_f value of .28. What does this indicate about the polarity of the unknown compound? [2]

- a) The unknown compound is nonpolar
- b) The unknown compound is polar**
- c) The unknown compound is neither polar nor nonpolar
- d) There is not enough information to answer this question

79) Which chromatographic technique depends on the highly specific interactions between pairs of biological materials such as enzyme-substrate? [1]

- a) Adsorption chromatography
- b) Ion-exchange chromatography
- c) Absorption chromatography
- d) Affinity chromatography**
- e) Gel-permeation chromatography

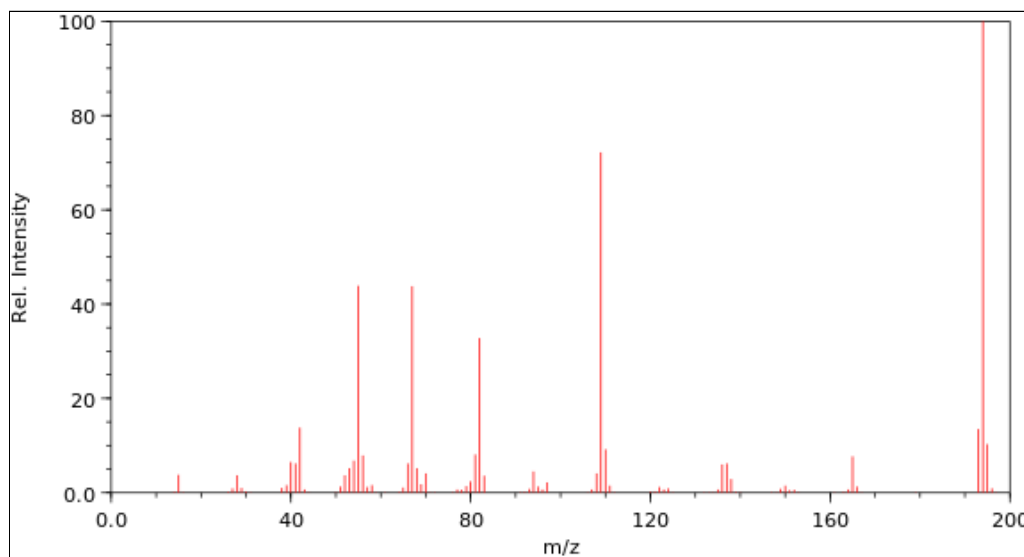
80) By what characteristic does eluate chromatography separate compounds? [2]

- a) Size
- b) Electronegativity
- c) Viscosity
- d) Polarity**

- 81) Which of the following statements is true about anion exchange chromatography? [1]
- a) The column contains negatively charged beads where positively charged proteins bind
 - b) The column contains positively charged beads where negatively charged proteins bind
 - c) The column contains both positive and negatively charged beads where proteins bind depending on their net charge
 - d) All of the above
 - e) None of the above
- 82) High performance liquid chromatography (HPLC) cannot be used to... [1]
- a) Determine the mercury content of a fish sample
 - b) Determine the caffeine content of coffee samples
 - c) Separate types of organic pesticides
 - d) Identify the various pigments from a leaf extract
- 83) In gas chromatography, if two solutes with short retention times co-elute (i.e. are not resolved), what is the simplest way to attempt to resolve the peaks? [1]
- a) Use a longer column
 - b) Use a shorter column
 - c) Use a higher column temperature
 - d) Use a lower column temperature
 - e) Use a more polar solvent
 - f) Use a different carrier gas
- 84) In forensic toxicology, all positive drug findings must be confirmed by a specific chemical test. the confirmation test of choice is: [1]
- a) HPLC
 - b) GC-MS
 - c) TLC
 - d) Eluate chromatography
- 85) What happens to the R_f value when the solute in a paper chromatogram is more attracted to the stationary phase? [2]
- a) The R_f value is large
 - b) The R_f value is small
 - c) There is not enough information to answer this question

Section F: Mass Spectroscopy [25 pts]

A strange liquid not endemic to the Amazon Rainforest was found and subsequently ran through a mass spectrometer. Identify what liquid was found and who it implicates. Use the mass spec diagram below to answer the following questions:



- 86) Identify the chemical that was found. [4] **Caffeine**
- 87) Who does this incriminate? [1] **Eric**
- 88) Identify the base peak. [2] **[Accept anything between 193-196]**
- 89) Identify the molecular ion peak. [2] **[Accept anything between 193-196]**

The following questions are unrelated to the Crime Scene:

- 90) True or **False**? One massive disadvantage of using Mass Spec in Forensic Science is that a large amount of a compound is needed to successfully identify it. [1]
- 91) What is the biggest use for Mass Spectroscopy in Forensic Science today? [2]

Testing for illicit drugs.

- 92) In which state of matter mass spectroscopy is being performed? [1]
- a) Solid
 - b) Liquid
 - c) **Gas**
 - d) Any of the above

- 93) Below are 6 compounds and 4 mass spec diagrams. Match the compounds to their respective mass spec diagrams. Compounds will be used only once, but not all compounds will be used. Match the letter of the compound to the appropriate mass spec diagram. [12]

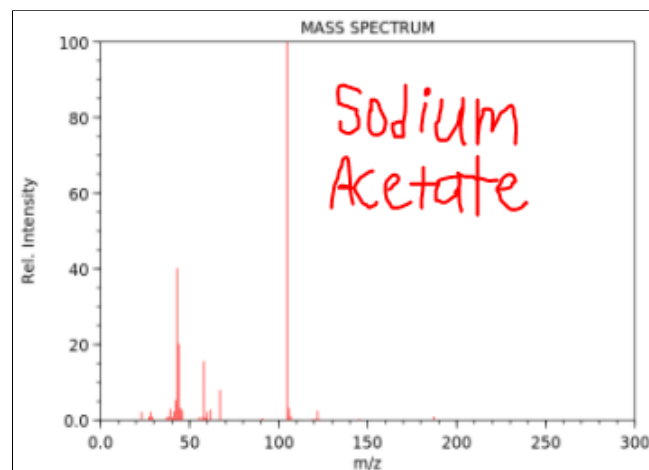
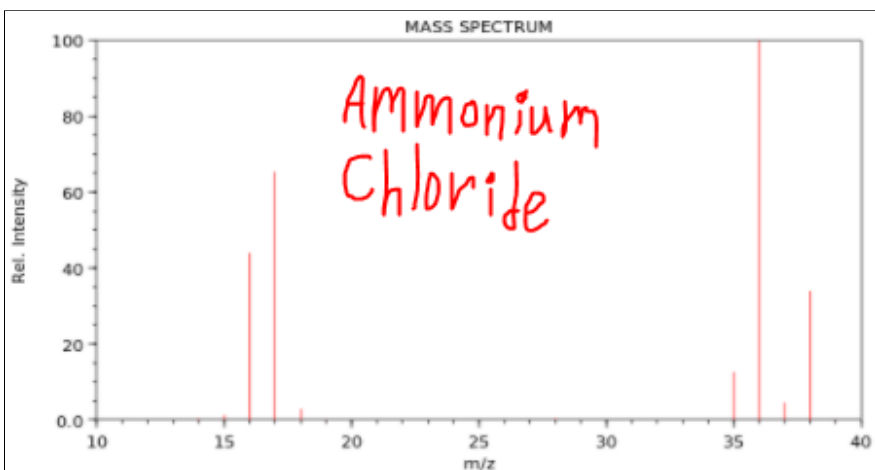
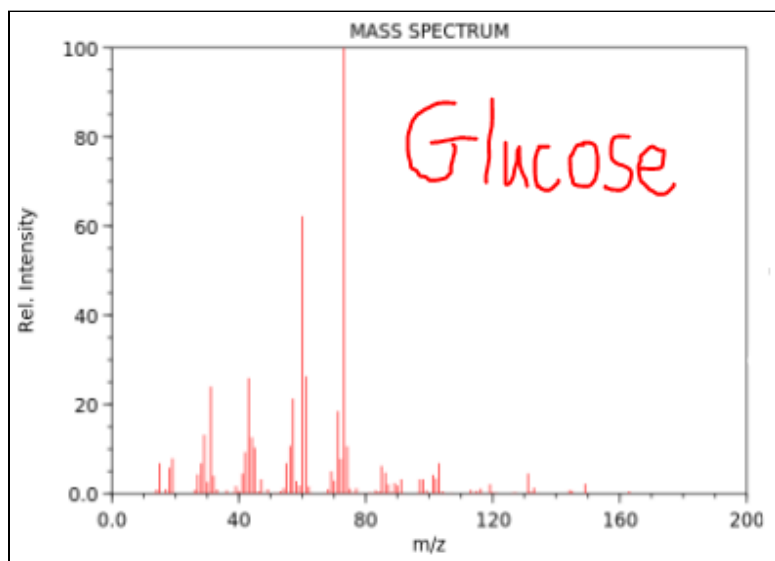
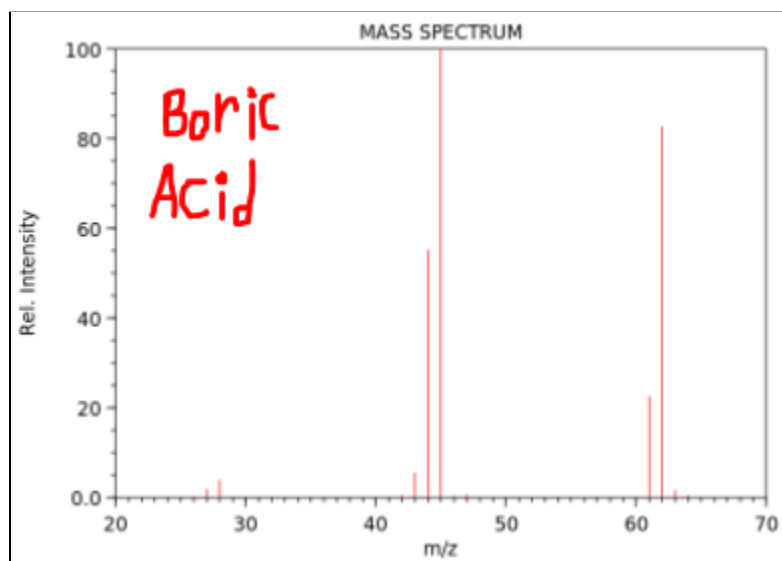
Compounds:

Lithium Chloride, Sodium Acetate, Boric Acid, Glucose, Ammonium Chloride, and Cornstarch.

Since these are official Forensics powders, you should already know their chemical formulas! However, I have included the approximate masses of all necessary elements:

Boron- 10.81 au; **Carbon-** 12.01 au; **Chlorine-** 35.45 au; **Hydrogen-** 1.008 au; **Lithium-** 6.94 au;

Nitrogen- 14.01 au; **Oxygen-** 16.00 au; **Sodium-** 22.99 au



Section G: DNA Analysis [25 pts]

A hair was found at the crime scene and DNA was extracted from it to be analyzed. Below are DNA samples from each of the suspects as well as the DNA sample found at the crime scene. Fill in the table and identify whose DNA was found. [7]

	Adenine	Cytosine	Guanine	Thymine
Eric Ma	32%	18%	18%	32%
Allen Chang	24%	26%	26%	24%
Jason Chang	24%	26%	26%	24%
Gwennie Liu	17%	33%	33%	17%
Andrew Zhang	27%	23%	23%	27%
Crystal Zhu	14%	36%	36%	14%
Crime Scene	17%	33%	33%	17%

94) Whose DNA was found at the Crime Scene? [2] **Gwennie**

95) What biological principle did you use to solve this table? [1] **Chargaff's Rule**

96) Which part of the hair can DNA be extracted from? [1] **The root**

The following questions are unrelated to the Crime Scene:

97) **True** or False? Very little DNA (only a nanogram) is needed for Forensic analysis. [1]

98) True or **False**? The only way that DNA is used in Forensics is to convict guilty individuals. [1]

99) In recent years, DNA Analysts have been developing technology to predict the phenotypes of individuals based on small samples of their DNA. Considering the current biases within the American Criminal Justice system, how might this be beneficial? [2] **There are a lot of racial biases in the American Criminal Justice system. If scientists are able to predict what a person will look like based on their DNA, this will decrease the number of convictions based solely on bias, and increase the number of convictions based on legitimate science.**

- 100) One hot topic in Forensic Science is the ethics of having a universal DNA database in the USA. List one pro and one con to having this. [2] **Pros-** Easy to match criminals/exonerate innocent people; decrease costs of investigations. **Cons-** Obstruction of individual liberty; gov't having too much power; info could be hacked and sold; racial/ethnic bias
- 101) Unfortunately, most DNA samples found at a crime scene are too small to be properly analyzed. Luckily, scientists have come up with an efficient method to amplify DNA samples. This method is abbreviated as PCR. What does PCR stand for?[1]

Polymerase Chain Reaction



- 102) List and describe the 3 steps of PCR. Include the temperature and what occurs in each. [6]
Denaturing [1]: strand of DNA heated to 95°C [.5] to separate it into 2 strands [.5];
Annealing [1]: temp lowered to 50-65°C [.5] to enable DNA primers to attach to template DNA [.5];
Extending [1]: temp raised to 75-80°C [.5] and new strand synthesized with Taq Polymerase [.5]
- 103) DNA profiling is complex, especially in criminal cases, Forensic analysts want to be sure beyond a shadow of a doubt that a suspect actually committed a crime. Because of this, multiple STR loci are tested and compared. With this knowledge, use the table below to determine if Suspect A or Suspect B's DNA matches the DNA found at the crime scene. [1]

Suspect B

STR Locus	Evidence Sample	Suspect A	Suspect B	Suspect B's Genotype Frequency for Each STR
D3S1358	15, 17	17, 17	15, 17	0.13
vWA	15, 16	18, 19	15, 16	0.22
FGA	23, 27	21, 23	23, 27	0.31
D8S1179	12, 13	14, 15	12, 13	0.34
D21S11	28, 30	27, 30.2	28, 30	0.06
D18S51	12, 18	14, 18	12, 18	0.11
D5S818	13, 13	9, 12	13, 13	0.29
D13S317	12, 12	12, 12	12, 12	0.21
D7S820	10, 11	9, 10	10, 11	0.26
CSF1PO	8, 11	11, 12	8, 11	0.18
TPOX	7, 8	8, 8	7, 8	0.30
THO1	9.3, 9.3	6, 9.3	9.3, 9.3	0.38
D16S539	9, 13	11, 12	9, 13	0.10

Section H: Fingerprinting [12 pts]

The following fingerprints were found at the crime scene. Identify the type of fingerprint and who it belongs to. Note that every fingerprint for this case is a right thumbprint.

Fingerprint A	Fingerprint B
	

- 104) Identify Fingerprint A. [3] **Ulnar loop**
- 105) Who does Fingerprint A incriminate? [1] **Allen**
- 106) Identify Fingerprint B. [3] **Double Loop Whorl**
- 107) Who does Fingerprint B incriminate? [1] **Eric**

The following questions are unrelated to the Crime Scene:

- 108) Jason and Allen Chang are identical twins. However, even though they have the same DNA, their fingerprints are totally different! Explain why this is. [2]

A person's fingerprints are formed when they are a 6 month old fetus in their mother's womb. Pressure on the fingers from the baby touching, and their surroundings create what are called "friction ridges." Because everyone as a fetus will touch against their mother's womb differently, even identical twins will have different fingerprints.

- 109) What is the most common type of fingerprint? [1]

Ulnar loop

- 110) You arrive at a crime scene and see a fingerprint in a pool of blood. What type of fingerprinting should you use to identify it? [1] **Ninhydrin**

Section I: Blood Spatters [18 pts]

- 111) There was a blood spatter found on the ground next to where the note was found. It was measured to be 1.85 in wide and 2.00 in long, and it was found 25.0 in away from a shoe print (treat this as the point of origin). Calculate the height of the point of origin (show your work and write the answer in significant figures). Who does this implicate? [5]

60.9 in tall, Gwennie

The following questions are unrelated to the crime scene:



- 112) From which side did the blood spatter originate from? (right or left) [1]

Left



Forensics Key

- 113) Identify which of the pictures above show low, medium, and high velocity spatters, and give one possible cause for the spatter. [6]

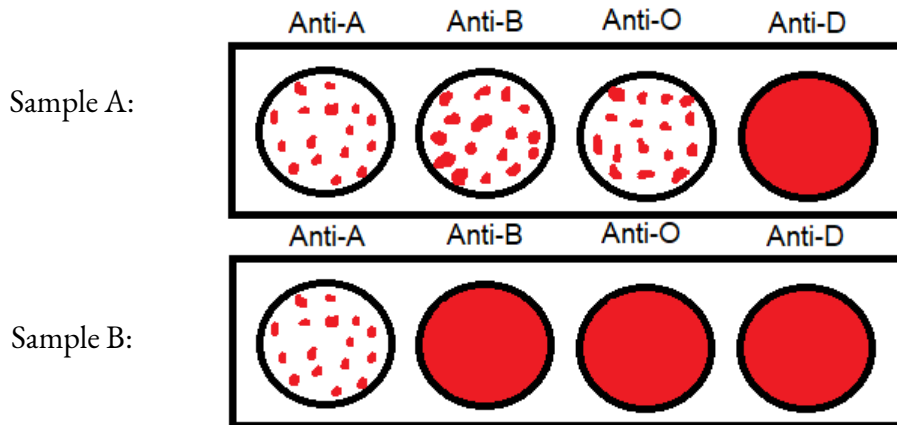
Low: nosebleed, medium: blunt force trauma (e.g: hit with baseball bat), high: gunshot

- 114) Identify which of the following are considered low, medium, and high velocity spatters given the diameter of the spatter: 0.2 mm, 1.5 mm, 2.3 mm, 3.8 mm, 4.9 mm, 7.0 mm [6]

High, high, medium, medium, low, low

Section J: Blood Typing [16 pts]

Two blood samples were found in the rainforest. One (the blood spatter) was found next to the note. This is the top blood sample. The second, the bottom blood sample, was found a few hundred feet away from the note. Below are the results of the serotyping tests for both of the aforementioned samples. Identify the type of the blood and which suspect it belongs to.



- 115) What type of blood was found in Sample A? [3] **AB+**
116) Who does this incriminate? [1] **Gwennie**
117) What type of blood was found in Sample B? [3] **A-**
118) Who does this incriminate? [1] **Jason and Allen**

The following questions are unrelated to the Crime Scene:

- 119) What is the most prevalent blood type? [1] **O+**
120) Where are antigens located? Where are antibodies located? [2]

Antigens are located on the surface of Red Blood Cells. Antibodies are located within the blood serum.

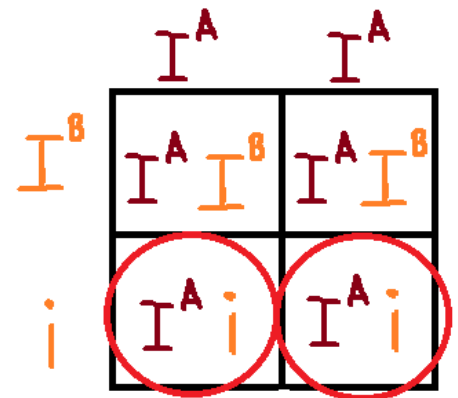
- 121) Why is blood typing such a concrete way for Forensic Scientists to link suspects to a crime scene? [1]

An individual's blood type isn't affected by disease, drugs, climate, occupation, living conditions, or any other physical circumstances. Tl;dr an individual's blood type is static and will never change.

Forensics Key

- 122) A woman named Leslie is homozygous for Type A blood. Her husband, Ben, is heterozygous for Type B blood. If the couple has triplets, what are the odds that they will all have Type A blood? [2]

1/8 or 12.5%



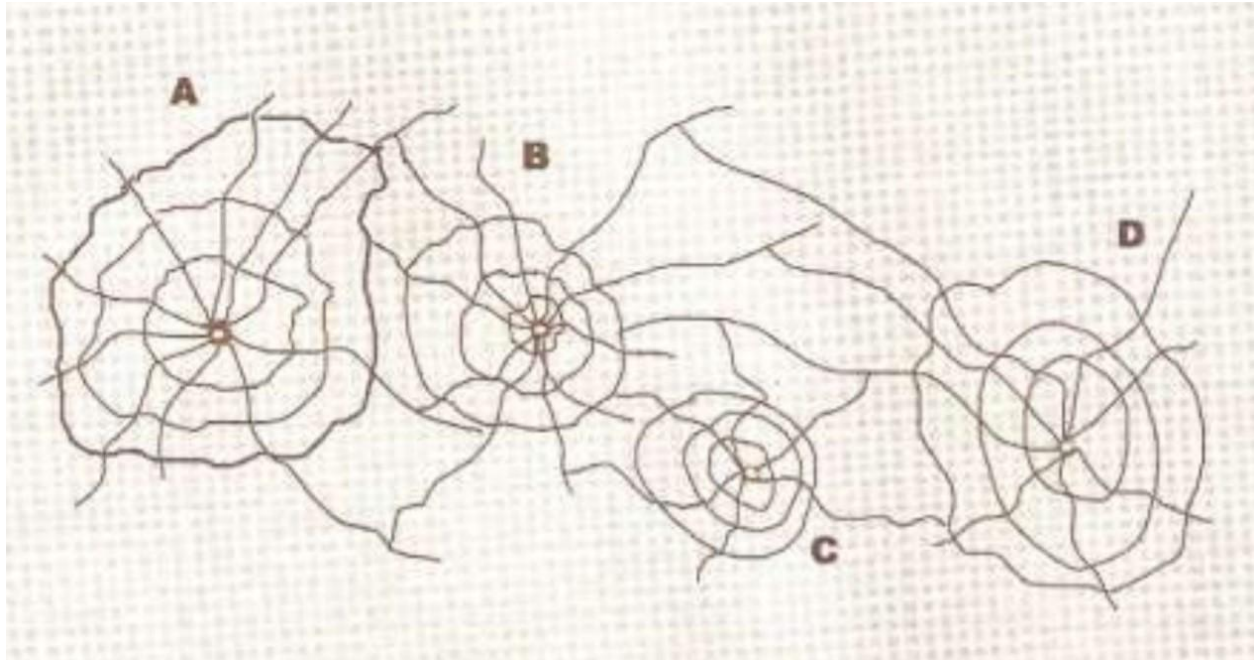
- 123) Imagine you have A- blood. Who would you be able to donate blood to? (List the blood Type Phenotypes) [2]

A+, A-, AB+, AB-

$$\frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{2} = \frac{1}{8}$$

Section K: Glass [24 pts]

The following section is unrelated to the crime scene:



124) Give the order of fracture of the glass depicted in the picture above: [4]

A,B,D,C

Glass	Index of Refraction
Pyrex glass	1.47
Crown glass	1.51
Flint glass	1.66
Tempered glass	1.52

125) A ray of light enters a pane of glass (from air) at 42.0° to the horizontal. If the angle of the refracted ray is 23.8° , what is the index of refraction of the glass? What type of glass was the pane of glass made of? (show work and give the answer in significant figures) [4]

1.66, flint glass

- 126) A ray of light enters a pane of glass (from air) at 50.0° to the horizontal. If the angle of the refracted ray is 31.4° , what is the index of refraction of the glass? What type of glass was the pane of glass made of? (show work and give the answer in significant figures) [4]

1.47, pyrex glass

- 127) A ray of light enters a pane of glass (from air) at 68.0° to the horizontal. If the angle of the refracted ray is 37.9° , what is the index of refraction of the glass? What type of glass was the pane of glass made of? (show work and give the answer in significant figures) [4]

1.51, crown glass

- 128) A ray of light enters a pane of glass (from air) at 26.0° to the horizontal. If the angle of the refracted ray is 16.8° , what is the index of refraction of the glass? What type of glass was the pane of glass made of? (show work and give the answer in significant figures) [4]

1.52, tempered glass

- 129) Why is tempered glass safer to use in automobiles than other types of glass? [4]

When tempered glass shatters, it breaks into cubes/dices rather than shards, so in a car accident, cubes will not cut the people involved in the accident as easily as sharp shards of glass will.

Section L: Entomology and Decay [11 pts]

The following section is unrelated to the crime scene:

- 130) You and your mom are going on your daily Government-Mandated Walk and stumble across a dead opossum. You notice that there are blowfly eggs hatching. Approximately how many days has this poor opossum been dead? [1]

Approximately 2 days.

- 131) It is sometimes said that certain species of insects are the first witnesses to a crime. What are the first insects to arrive at a corpse? How long does it take them to arrive? [3]

Calliphoridae (blow flies) and Sarcophagidae (flesh flies) are the first species to arrive. They arrive within minutes of death.

- 132) Reference the insects from the previous question. Which part of the body is not a common area for them to lay their eggs? [1]

- a) Nose
- b) Ears
- c) Mouth
- d) Eyes
- e) Armpits
- f) Pelvic Regions

- 133) Which stage of decay is characterized by a significant reduction in insect activity? [1]

Advanced Decay

- 134) If a Forensic Entomologist cannot personally be at a crime scene, what should one of the other experts (who is physically there) do with the insects found on the body? [3]

Keep the insects alive [1] and put them in a jar [1]. Feed them some sort of meat (tuna; beef; etc.) to keep them alive. [1]

- 135) If an abnormal concentration of maggots is found on a corpse (e.x. on the body's leg) what can be deduced? [2]

There is a wound there, which is why the maggots are there in such high numbers.

Section M: Seeds and Pollen [13 pts]

The following section is unrelated to the crime scene:

- 136) What is the name for the study of pollen? [1] **Palynology**
- 137) **True** or False? Pollen must be viewed underneath a microscope. [1]
- 138) True or **False**? Pollen is classified as physical evidence. [1]
- 139) There are many advantages to using pollen in Forensic cases. List 3 of them. [3]

Pollen is very durable; very specific to certain locations; still intact after lots of time; spore dispersal; small in size; very species/subspecies specific

- 140) Sadly, even pollen isn't perfect. List one drawback to using pollen in Forensic cases. [1]

Very expensive; shortage of information in a database; very few forensic palynologists in the country(/world)

- 141) Why do Forensic Scientists prefer studying pollen to plants/botany? [1]

Pollen is much more durable than plants; Forensic Botany is an even smaller field than Forensic Palynology

- 142) One specific use of pollen in Forensics is to determine where something originated. In what specific types of crimes would this be useful? [1]

Illicit drugs; money; antiques; food (movement of illegal goods)

- 143) What are the 3 components of a seed? [3]

Embryo, Endosperm, Seed Coat

- 144) **True** or False? One way that seeds are used in Forensics is analyzing the fruit/vegetable seeds in the content of one's stomach. [1]

Section N: Tracks and Soil [14 pts]

The following shoe print was found in the forest next to the note and the blood spatter:



These are the shoes that the suspects wore on the day of the crime:



Andrew

Crystal

Allen

Eric

Gwennie

Jason

145) Whose shoe matches the print? [1]

Gwennie

The forest where the birds were taken is an interesting place, as there are different types of soil at different locations within the forest. Soil samples were taken from the bottom of the shoes of each of the suspects and analyzed. Identify the type of soil found on each of the suspects.

146) Eric: 90% clay, 5% silt, 5% sand [2]

Clay

147) Allen: 70% clay, 15% silt, 15% sand [2]

Clay

148) Jason: 70% clay, 15% silt, 15% sand [2]

Clay

149) Gwennie: 90% clay, 5% silt, 5% sand [2]

Clay

150) Andrew: 30% clay, 5% silt, 65% sand [2]

Sandy clay loam

151) Crystal: 35% clay, 30% silt, 35% sand [2]

Clay loam

152) The soil at the crime scene was also collected and analyzed. If the soil type was clay, who could this implicate? [1]

Eric, Allen, Jason, and/or Gwennie

Section O: Ballistics [13 pts]

The following section is unrelated to the crime scene:

- 153) List the three types of ballistics. [3]

Interior ballistics, exterior ballistics, and terminal ballistics

- 154) Imagine you are a Forensic Scientist who has just arrived at the scene of a shooting. What velocity of blood spatters should you expect to find? [1]
- a) Low Velocity
 - b) Medium Velocity
 - c) High Velocity
- 155) What material are most bullets/projectiles made out of? [1]

Lead

- 156) Fill in the blank: Firearms convert _____ energy into _____ energy. [2]

Firearms convert **Chemical** energy into **Kinetic** energy.

- 157) Why is tracing the flight path of a bullet useful for Forensic investigation? [1]

It can tell you which direction a bullet was shot from.

- 158) Even though Forensic Scientists would love to successfully be able to calculate a bullet's flight path, this is quite a difficult task. List three factors that could affect a bullet's flight path. [3]

Gravity; air resistance; wind/other environmental factors; defective rifling, poor loading, or a badly cast bullet [need 3]

- 159) One very distinctive feature of a legally purchased firearm is a clearly engraved serial number. However, since these serial numbers are stored in a database along with the identification of the person who purchased that respective firearm, many criminals attempt to "erase" them from the firearm. What is one common way that this is attempted? [1]

Filing or grinding

- 160) True or **False**? Only the chemical properties of gunshot residues are analyzed. [1]

Section P: Analysis [129 pts]

Who committed the crime? Who was innocent? Use the space provided to explain who was the one who committed the crimes. Be sure to include which evidence proves this, and who was innocent and how you know. If you need more space, feel free to go to the back of this paper. Make sure to only use the samples indicated to be found at the crime scene.

For each of the suspects listed below, state any and all evidence that either incriminates them or proves them innocent [92].

Eric [26]:

- glucose from soda [2]
- sucrose from soda [2]
- sodium acetate from salt and vinegar chips and photography [2]
- sodium carbonate from photography [2]
- PETE from soda bottle [2]
- PP from bag of chips [2]
- cotton from denim jeans [2]
- nylon from nylon shirt [2]
- Human hair [2]
- ballpoint pen from note [2]
- Caffeine was found and he was drinking soda (mass spec) [2]
- A double loop whorl fingerprint was found [2]
- clay soil [2]

Allen [14]:

- PC from model bird [2]

Forensics Key

-polyester from polyester shirt [2]

-spandex from spandex underwear [2]

-Human hair [2]

-An ulnar loop fingerprint was found [2]

-A- blood found in forest [2]

-clay soil [2]

Jason [12]:

-PC from model bird [2]

-nylon from nylon shirt [2]

-silk from silk underwear [2]

-Human hair [2]

-A- blood found in forest [2]

-clay soil [2]

Gwennie [18]:

-cotton from denim jeans [2]

-polyester from polyester shirt [2]

-Human hair [2]

-sharpie from ransom note [2]

-Gwennie's DNA was found [2]

-Type AB+ blood was found [2]

-blood type matched blood from spatter, whose origin matches her height (5'1) [2]

-track matches her shoe print [2]

-clay soil [2]

Andrew [12]:

-calcium carbonate from antacid for heartburn [2]

-lithium chloride for bipolar disorder treatment [2]

-cotton from denim jeans and cotton shirt [2]

-Human hair [2]

-ballpoint pen from note [2]

-sandy clay loam soil [2]

Crystal [10]:

-boric acid from insecticide [2]

-cotton from denim jeans [2]

-wool from wool sweater [2]

-Human hair [2]

-clay loam soil [2]

For the final conclusion, please use motive and the evidence listed in the previous questions to determine which of the suspects are innocent and which are guilty [37].

Conclusion:

In conclusion, Eric [6] and Gwennie [6] stole Blu and Jewel for ransom. Eric had the motive of needing money for college [1], and Gwennie had the motive of needing money for knitting supplies [1]. Due to their strong motives and overwhelming amount of physical and genetic evidence [1], they are the clear perpetrators of this crime.

Allen [3] and Jason [3] did not commit this crime. They both had a legitimate reason for being in the Rainforest [1], and there was not a lot of evidence linking them to the crime scene [1]. Additionally,

they had no real motive to steal the birds for ransom [1] and just wanted to study them to learn how they fly [1].

Andrew [3] also did not commit the crime. He had a legitimate reason to be in the Rainforest (his health problems) [1]. Even though he also has a decent motive of needing money [1], there is not enough evidence to link him to the crime [1].

Crystal [3] also did not commit the crime. She doesn't have a very strong motive (yes, she wants the birds as pets but would have no reason to hold them for ransom [1]) to want to steal the birds and her alibi holds up [1]. Additionally, not much specific evidence links her to the crime scene [1].

Post-test instructions:

- ➔ Thank you for competing in BirdSO Invitational Forensics! We really hope that you enjoyed our test as the two of us had such a great time writing it!
- ➔ This Forensics test was written by Camille Zhang (Mira Loma '20, Brown '24) and Zoe Goldblum (Cumberland Valley '20, Penn State '24).
- ➔ Feel free to reach out to us here:
 - ◆ Camille- camillezhang2002@gmail.com/Camel#4485 (Sections A, B, C, E, J, K, N)!
 - ◆ Zoe- zsg5037@psu.edu/flowersforzoe#1145 (Sections D, E, F, G, H, I, L, M, O)!
- ➔ Please fill out the linked feedback form: <https://forms.gle/oYbACwKK8623oPYB8>. I love any and all feedback about the tests I write! (Zoe)
- ➔ Have a great rest of the competition and good luck in the remainder of your events!!