

## Chapter 15

### Murder and Mayhem in Non-Majors Biology

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## Introduction

Scientific inquiry has some features in common with crime solving: an intriguing puzzle, clues, and secrets to be exposed. The detective and the scientist both seek to reveal the truth through gathering evidence, making inferences, and formulating, testing, and revising hypotheses. They also share the possibility that the truth may never be known. The evidence may support a hypothesis, but the hypothesis cannot be proven to be true. Furthermore, the modern criminologist may employ techniques from the biologist's tool kit, including blood typing and DNA analysis.

The prosecutor's job in court is to present evidence in support of the hypothesis that the defendant is guilty. He or she is not required to prove guilt beyond a shadow of a doubt, but to

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present sufficient evidence to remove reasonable doubt. Similarly, scientists accumulate evidence, often from a variety of sources, to support their hypotheses. The more evidence there is in support of a hypothesis, the more certain we can be that it is correct. On the other hand, a single piece of evidence may exonerate a suspect, and a single experiment may falsify a hypothesis. Thus a little murder in the biology lab is a good way either to introduce or to review the concept of how scientific knowledge is accumulated.

### **Goal**

Students synthesize what they've learned about the scientific process and use it to solve a complex problem.

### **Objectives**

1. Students use observations and thinking skills to make inferences and form and test hypotheses.
2. Students use blood typing, simulated restriction analysis and other physical evidence to test hypotheses.

### **Setting the Scene**

When students come into lab, they find that they have entered a crime scene. Blood and an outline of the body are still on the floor. Students are given a police report with the details of the murder, and some other general information. Each student is assigned to play a role as one of the people involved in the case. One is the killer, but he or she will not be aware of this. Each person receives a nametag and a packet of information that pertains specifically to his or her character, including a description of the person and his or her interactions with the victim, and physical evidence (fingerprint, footprint, blood type, and DNA sequence). The students' task is to gather evidence, form a hypothesis, gather more evidence to test it, perhaps revise the hypothesis, and finally reach a conclusion. Along the way, evidence will clear some suspects and leave others under the "umbrella of suspicion."

### **The Game is Afoot**

After receiving instructions, students are given time to peruse their packet of information. Characters with related plot-line involvements meet with each other and may exchange what they know. They then work as a team to question other suspects. That is, each person interviews other suspects and reports back to the group so that information can be pooled. A list of suggested questions is provided. When a group thinks they have identified a likely suspect, they may request a comparison of physical evidence. That is, they have formulated a hypothesis to test.

The lab instructor acts as the prosecutor. He or she evaluates the evidence brought in by the detectives and determines whether they have sufficient grounds to subpoena further evidence, which allows the instructor to control "play." The instructor has the physical evidence that has been found at the scene, and reveals one piece at a time for hypothesis testing.

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The first piece of physical evidence supplied is the blood type. It may exclude the suspect (prove the hypothesis to be false) or fail to exclude him/her (support but not prove the hypothesis). Depending upon the conclusion, the group may pursue the same hypothesis and request the next piece of evidence, the footprint. Or they may resume questioning suspects in order to gather evidence for a new hypothesis. There are four lines of physical evidence to follow, revealed in this order: blood type, footprint, fingerprint, and DNA analysis. Blood type and footprints are common to several suspects, so they are the least conclusive. Two fingerprints were recovered from the murder weapon, but an innocent person could have handled it previously. The DNA analysis (carried out by cutting paper strips) is the only conclusive evidence – but there is even one situation in which it is not conclusive!

### **Resolution**

The first team that assembles enough evidence will bring the case to trial. They present their evidence to the class: motive, blood type, footprint, fingerprint, and DNA analysis. The class, as jury, may vote on whether they have identified the correct suspect.

Although in a real criminal case, just as in science, the true fact may not be knowable, we elected to have the satisfaction of a “Perry Mason” scenario. The identity of the killer is revealed, and he or she reads a confession explaining how and why the murder was committed.

### **Student Assessment**

Students write an essay on how solving this murder illustrates the principles of scientific investigation.

## Materials

### List of Materials

*Suspect Packets (one for each student) containing:*

1. General evidence including: police and medical examiner's report, newspaper article, background, suspect list, evidence collection sheets, and hints for interviewing suspects
2. Description of the character
3. Suspect's physical evidence: paper DNA sequence, blood sample code number, fingerprint, and footprint

*Killer Identity Packet (one per lab section) containing:*

1. Paper DNA sequence and "restriction enzyme" to use
2. Footprint
3. Fingerprint
4. Blood type
5. Confession

*Blood Typing Kits (Carolina Biological #BA-70-0124 or Wards #36W0019) containing:*

1. 4 types of artificial or aseptic blood
2. Anti-sera to blood types
3. Instructions for interpreting coagulation results

Plus:

4. Extra typing cards (Carolina Biological #BA-70-0572)
5. Extra stirrers (Carolina Biological #BA-70-0550)

### Producing the Evidence

#### *General Evidence*

Appendix A contains the reports from the police and the Medical Examiner. The evidence collection sheet and hints for interviewing suspects are in Appendix B. A sample newspaper article is located on the ABLE website (<http://www.zoo.utoronto.ca/able/volumes/vol-22/minor/index.htm>).

#### *Description of the Character*

Twenty-five sample suspects descriptions are available on the ABLE website. They can be modified to fit your institution.

#### *Physical Evidence*

**DNA Strips** Appendix C contains 25 different DNA strips that may be photocopied and used for sections of twenty-five or fewer students. The code for generating the DNA strips is also included in Appendix C in case you need to generate more than twenty-five sequences. This code generates random sequences; no two will be alike. It is written in PERL and can be run on any computer that has PERL installed on it.

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**Footprints** We collected 25 different shoes from various people and scanned their soles to generate the number of “prints” needed. You may make your own footprints this way, or download graphics files of scanned footprints from the ABLE website. If you wish to make your own footprints and don’t have a scanner, simply photocopy the soles of the shoes.

**Fingerprints** We took index finger prints from 25 different people. These prints were then scanned for use in the packets. “Official” print cards like the police use have been scanned and are available for download from the ABLE website.

**Blood Type** One blood-typing kit from Carolina or Ward’s provides four different blood types and is adequate for 1-4 sections. For 20 lab sections of 24 students each, we used a total of six kits. This allowed us to assign a different vial of blood and a unique blood sample code to each of the 24 suspects (some suspects have the same blood type). This quantity of blood was sufficient for a total of 480 students. If you have fewer vials of blood than suspects, aliquot blood samples into smaller containers such as Eppendorf tubes so that you have one sample for each suspect.

Write the blood sample code (1–24) on each suspect’s packet and on the sample vial. When blood evidence is subpoenaed the instructor supplies the appropriate blood sample for testing.

Keep the blood samples refrigerated.

### **Assembling Packets**

#### *Killer Identity Packet*

Assemble the killer identity packet first since suspect packets will be based on it.

Choose one of the suspects who has a strong motive as the killer. Put his or her confession in the envelope. Add the physical evidence that was found at the crime scene. Samples of killer information are shown in Appendix D. However, instead of having the information pasted up on a single sheet of paper, the evidence should consist of loose pieces so that each piece can be revealed without showing the rest. The physical evidence consists of:

- A card identifying the blood type found at the scene (note: this is not the victim’s blood type, so it is assumed to belong to the killer,
- The footprint found at the scene,
- Two fingerprints found on the murder weapon (the students are not told which one actually belongs to the killer), and
- A strip of paper that represents the DNA sequence, along with the name of the “restriction enzyme” that will be used to “cut” the DNA.

This physical evidence is chosen at random from the evidence you have already prepared. When all the evidence is assembled, seal the envelope.

If you have multiple sections, create a different killer packet for each section. This prevents early classes from spoiling the fun for later classes.

### *Suspect Packets*

Twelve suspects are essential to the game because of their roles in the plot. They are designated as core suspects in the descriptions on the website. When preparing the packets, encode the envelopes to indicate to the instructor which packets must be assigned to players. If there are fewer than 12 students in a lab section, the instructor should tell the story of the core characters that were omitted.

Since you have already assembled the killer's packet you know who did it. Assemble that suspect's packet first, matching the DNA sequence, fingerprint, and footprint with the ones placed in the Killer Identity Packet. Add a blood sample code that points to a blood sample of the correct type to the front of the packet.

Assemble the remaining packets using a random distribution of the remaining shoe prints, DNA sequences, fingerprints and blood types. The only rules are to make sure that:

1. Multiple suspects have the same blood type as the killer
2. Multiple suspects have the same footprint as the killer
3. No two fingerprints are alike
4. The "extra" fingerprint in the killer packet belongs to one of the suspects (not the killer)
5. The twins have matching DNA sequences, but everyone else has a different sequence (identical twins have the same DNA sequence but different fingerprints).

The general evidence (same for everyone) and the suspect character description (unique to each suspect) also go in each packet.

A separate set of suspect packets is needed for each lab section.

### **Adapting the Generic Murder**

When developing this laboratory for our students, we used local characters and situations, including faculty, administrators, and athletic coaches, to add some humor and fun. We also developed a generic version of the game for adaptation at other institutions. This version is posted at the ABLE website (<http://www.zoo.utoronto.ca/able/volumes/vol-22/minor/index.htm>). You may download the materials and use them as templates for devising your own plots based on local personalities.

Part of the fun of a fictional murder is choosing a victim. James Watson came to mind because students had read *The Double Helix*. This choice made it easy to create plot lines. The character could either be real or fictitious. What is essential is that he has reasons for being in contact with a wide range of suspects on campus.

Just as enjoyable is concocting motives for a wide variety of people. With Watson as the victim, a few motives suggested themselves. Others were invented. In all cases, we took extraordinary liberties with the facts of Watson's personality and character to create plausible motives. Although there were characters that had unpleasant interactions with Watson, we found that students immediately rejected any suspects whose motives were not perceived as strong enough. The victim must therefore exhibit some truly *bad* behavior. This also means that suspects must be hiding some truly awful secrets, which are also complete fabrications.

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The game can be adapted for multiple lab sections by having numerous suspects with strong motives, each of whom can be the killer in different lab sections. It is a simple matter to change the physical evidence to match the designated killer. Instructions on how to assemble suspect and killer-identity packets are included in this article.

### **Notes for the Instructor**

#### **Introduce the Forensic Evidence**

This game is based on very basic forensic evidence. Students may have heard about the methods used in the game but may not know how they actually work. The instructor should present a brief introduction to techniques before the start of the game. We suggest the following topics:

1. New techniques based on biological methods such as RFLP analysis, chemical detection, and blood assays are available to criminal investigators.
2. The principles of blood typing include ABO and Rh blood groups, and antigen/antibody interactions. ABO/Rh typing is used in the game but the instructor may want to explain how additional analyses are used to strengthen an actual case.
3. The basic principles of DNA analysis include the use of restriction enzymes, electrophoresis, and visualization methods. The instructor should briefly explain the methods and how they are simulated by the paper strip analysis that is done in the game.

#### **Tell the Story Behind the Murder**

Set the scene for the crime. Dr. James Watson has come to campus. He visited with various people, spoke to a class, and was interviewed for the school newspaper. Now his body has been found in a biology lab, apparently bludgeoned with a textbook. A body outline is on the lab floor; there is a smattering of (artificial) blood and tracks around the room. A bloody textbook can be seen in an evidence bag. Everyone in the room is a suspect, and everyone will be trying to identify the killer.

#### **Assign Characters**

Assign roles by giving each student a suspect packet. There are 12 characters that are essential to the plot; be sure they are assigned. Students should wear nametags to identify themselves.

Group students into teams by “suspect type,” for example, the administrators, the coaches, the faculty, and so on.

The object of the game is to be the first team to identify the murderer.

General background information, including Watson's itinerary and newspaper interview, the police report, the medical examiner's report, a list of suspects, evidence collection sheets, and hints for interviewing suspects, is provided to everyone.

Each suspect also has a unique character profile and personal physical evidence that he or she should not share until asked.

When they are being interviewed, suspects may not lie or withhold information, although they may be evasive.

### **Explain the Procedures of the Game**

Explain the "evidence collection sheet" that is in the packets. Teams of students will work together to gather evidence. They will interview suspects until they are able to make an initial hypothesis about the killer's identity.

To gain each piece of physical evidence, the team members must first present their reasoning to the instructor.

When a group has formed a hypothesis, they will present their evidence to the instructor out of earshot of the rest of the class. If the instructor judges that sufficient evidence has been amassed, he or she will subpoena the blood type code of the suspect and provide the team with the appropriate blood sample vial. The team then performs a blood type test on the suspect's blood. The instructor will reveal the blood type that was found at the scene to this team after the test is completed.

With this evidence in hand, the team resumes interrogating suspects until they have either gathered additional evidence in support of their initial suspect, or (if that suspect was excluded by blood typing) identified a new suspect. In this way, students repeatedly test and revise hypotheses.

Evidence will be revealed in this order: blood type, footprint, fingerprint, and DNA. Footprints and fingerprints are compared by visual inspection. "Restriction analysis" of the DNA is performed by using the "enzyme" to cut the DNA strips at specified recognition sequences. The team performs the test both on the suspect's DNA and on the crime scene DNA and compares the results.

As a first step, students should take plenty of time to read the information in their packets. They then begin gathering information by interviewing others in their group. After learning what they can from other group members, they should then formulate a strategy for interviewing the other suspects and begin the interviews.

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### **Conclusion**

Once a team thinks that they have solved the murder they will present their case to the class. The class acts as a jury, deciding whether the accusing team has identified the right suspect. If the correct suspect has been accused, the instructor will ask the murderer to read his or her confession. If the accusers are not correct, the game should continue until the murder is solved.

### **Evaluation**

At the conclusion of the game bring the class back together and discuss how the process of scientific inquiry was followed in solving the murder. Our students were asked to submit the evidence collection sheet as well as a one-page essay on how solving this murder case illustrates the process of scientific inquiry.

## Appendix A Police and Medical Examiner Reports

### Official Incident Report Filed By Clemson Police Department

**Victim:** Dr. James D. Watson, discoverer of the structure of DNA, father of molecular biology and author of *The Double Helix*.

**Cause of Death:** Bludgeoning with Biology Text

**Time and Location of Discovery:** 5:15pm, Wednesday, November 24, 1999, Room 324 Long Hall

**Time of Death:** Between 4:10 and time of discovery on the same day.

**Discovered by:** Dr. Bill Surver, Chair, Dept of BIAE

**Suspects:** Numerous students, faculty, and administrators from Clemson University and former acquaintances of Dr. Watson.

#### Circumstances:

1. Dr. Watson delivered an address to Dr. Kenyon Revis-Wagner's class from 2:30-3:45pm on the day of the incident.
2. A blood stained copy of *Biology Concepts and Connections* by Campbell, Mitchell, and Reece was found laying to the left of the body.
3. Autographed copy of *The Double Helix* found in victim's right hand.
4. Blood of at least two types found at in the room and in the west stairwell.
5. Partial footprint found in blood spatters.
6. Multiple fingerprints on suspected murder weapon.
7. Entrance to room possible from hallway or through small room off to the side.
8. Open bottle of fly nap on laboratory counter.
9. Some signs of struggle.
10. Strands of brown hair found on lapel of the victim.

#### Medical Examiner's Report

**External:** Victim shows major contusions to the thorax and head. Clavical and number 1 and 2 ribs show simple breaks. Occipital bone of skull shows compound fracture and hematoma

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measuring 6 cm x 16 cm. Thorax contusion shows indication of footprint (partial print recovered).

**Internal:** Internal cranial exam indicates severe brain swelling at time of death. Thorax examination indicates bruised pleura but otherwise unremarkable. Victim has no appendix. Additional examination unremarkable.

**Hematology:** Blood profile assays within normal limits for age.

**Toxicology:** Evidence of out of parameter levels of tri-ethanolamine. No other significant toxicology concerns.

**Cause of Death:** Blunt force trauma to occipital region of skull.

Respectfully submitted by Dr. Hugh Dunit, Chief Medical Examiner

## **Appendix B Evidence Collection**

### **Putative Perpetrator:**

### **Circumstantial Evidence:**

Preliminary Hypothesis of who-done-it and why:

### **Blood Test Results:**

Additional Circumstantial Evidence:

Revised Hypothesis of who-done-it and why:

### **Footprint Results:**

Revised Hypothesis of who-done-it and why:

### **Fingerprint Results:**

Revised Hypothesis of who-done-it and why:

### **DNA Evidence:**

Case for Accusation:

## Appendix C DNA sequences

### 25 randomized DNA strips

ATCAGCCAGCTAGTAAACGTACGGTTTGTCGTATTGTCCACCGCTATGCTTT  
CACCTTTAT

GCCACTCGTAGGGTGTACACGCCGACTGAATCGTAAAAAGATCATAAAAT  
TTGGGAGATG

ATCCGAGTCCACCCAGTGGGGAAGTCAACACGGCGAGAAGGGCGACCAC  
AAAAATACAGC

TGCAAACCGCCGATCCTCCGCACTCGTCCGGCAACCCGCATACCGGTCCT  
GTGCTATTCC

CTACGCTGAAGCATCCACCCTTTGGTCGAGGCCATTACGGGTATGGATC  
GGTCCCGCCT

TCAACAAACTCTATGATATGTTTATGGAAAGCCGGTGACGCTTCTTCTTC  
GACCGGGTAG

GAAGGCACTCTGGCCGGCCTTCGATCTGCCATCTAAATCGTGTTTACTAG  
TCGATTCTTA

AGCCACATAACTGTCCGAAAGCTGATGTATCGTGGATCGAAAACCGTAAA  
CAACTGGCGC

GCCGCGAAGCTGAAAAGCGCGTCGTGTCCTAATTCCCCGAGTATCTTACG  
GAGATTCCCT

CTCCCACGTCGAACCTCATGTTACCAACCTATATCAAGCCTAAAAGTGG  
GTAAATCGAT

TCCGCCCTCGATTGAGCCCTTCTAAACGGGGGTCCGGAGATTAGCCGTTT  
TTCTCAAGTC

GTACACTGGTATATCGCTGCATACTTCCTTATGAAACCGCCAGGACTTAG  
AAGCTAGTTC

ACAGCGTGAAGTGAACCAAGACTCTTGTCTGAGGGATATATTGAAGTTAT  
CCATTCCTGT

GTAGCCAACACCGACAATGTAATTACGGAGGCCGACGATCGAGCATGGC  
ACAGAAGACCT

AGATCGACTCTAAGATAAAAAGCTACAAGGATGATCATTTCATTTAAGGGC  
GAATCGTCAC

TAAGAGATACAAAAAGATTCTTGCCGTCCACGATCGTCATCATCGCATGT  
ATCACGCTGG

CTATCTAAGGTAGGTCTACGTCCAAGAGGAATAATTCCATTATTGGATTA  
CATGGGTTCA

AATTCGGTTTACAACCTGACGCAGAGCAAGCCACGACTACTACCTGGCCC  
AAATAAATGT

GGTACTTTGCGCGCAATTGGGTTGTCTGCGTTCGACGGACCTCTTTGCCGC  
CGGCATTCC

ACATAGGGGAACCAAGTGCGCAATATGTAAAGGCTGGCCTGCGGCCAGG  
CTAATCAACTG

TTAACTGGCCGAACTCGTTTTCGGTTGTCTGAGATTCGTACTAAGACGCGGG  
AACGGATCGA

CCATAGTCCCCTAGCACGCACGGGCCTTCTGAGTTGGACATAGCCTTCTG  
ATTTTCTTGA

TAACTACTGTGGTTTCTTCCACGAACCGTAGTACTATGTCAGTCATCATC  
ACCTCCTCG

AGTACGGTAACTGACTGTGTACGTACCGTACAGGGTTCACTTACTATCCG  
ATACCGACAC

GCTCGTTTGCATACTGGAAAATATTCGACATGTAAAAAACGATTCACGT  
CAGTGGTCTT

## DNA Strand Generation

This code will run on any computer with PERL installed. In the first "for string" below the 25 may be replaced with any number to generate a specific number of DNA strands (e.g. replacing 25 with 50 would generate 50 strands. In the second for string the number 60 may be replaced to generate a DNA strand with a different number of bases (e.g. replacing 60 with 120 would result in a strand with 120 bases instead of 60).

```
#!/usr/local/bin/perl -w
open (DNA_FILE, ">dna.txt");
for ($j = 0; $j < 25; $j++) {
    srand( time() ^ ($$ + ($$ << 15)) );
    for ($i = 0; $i < 60; $i++) {
        $basenum = int(rand 4);
        SWITCH: {
            if ($basenum == 0) { $base = "A"; last SWITCH; }
            if ($basenum == 1) { $base = "C"; last SWITCH; }
            if ($basenum == 2) { $base = "G"; last SWITCH; }
            if ($basenum == 3) { $base = "T"; last SWITCH; }
        }
        print $base, " ";
        print (DNA_FILE $base, " ");
    }
    print "\n\n";
    print (DNA_FILE "\n\n\n");
    sleep 5;
}
```

## Appendix D Sample Killer Information

### Who Done It!!!!

#### Section: 1

**Killer ID: President James Barker**

**Blood type: O+**

**DNA:**

T A T C A T G C T T T C C A A T T A T G G G C C G G A G G C C A  
G G A C G C T T T T A G G A A G A T G A G A G G G A G A

**Restriction Enzyme Used: cattase = cuts after CAT and between 2<sup>nd</sup> and 3<sup>rd</sup> T in TTT sequence**

**Killer's fingerprint:**



**Finger Prints on body:**



**Footprint at Scene:**



# Murder and Mayhem

**Section: 2**

**Killer ID: Dr. Jerry Waldvogel**

**Blood type: O+**

**DNA:**

C G G T G T T G C C G G T T A G C G T T A T G G G T T C T G G T  
A G G A A C T C T C A G A C A A C G C A A G A A T T T C

**Restriction Enzyme Used: Tase= cuts between double Ts**

**Killer's fingerprint:**



**Finger Prints on murder weapon:**



**Footprint at Scene:**

