The Tyrolean Alps border western Austria, northern Italy, and eastern Switzerland. They are popular with tourists, hikers, mountain climbers, and skiers. In 1991, two hikers discovered the remains of a man in a melting glacier on the border between Austria and Italy. They thought the man had died in a hiking accident. So, they reported their discovery to the authorities.

Initially authorities thought the man was a music professor who disappeared in 1938. They soon learned that the music professor was buried in a nearby town. Artifacts near the frozen corpse indicated that the man died long before 1938. The artifacts were unusual. The man, nicknamed the Iceman, was dressed in leggings, a loincloth, and a goatskin jacket. He had a bearskin cap. His shoes were made of red deerskin with bearskin soles. They were stuffed with grass. A copper ax, a longbow, a quiver containing 14 arrows, a wooden backpack frame, and a dagger were found at the site.

A Controlled Experiment

The identity of the corpse was a mystery. Several people hypothesized about his identity, but controlled experiments were needed to unravel the mystery of who the Iceman was. Scientists and the public wanted to know the identity of the man, why he had died, and when he had died.

Identifying Variables and Constants

When scientists design a controlled experiment, they have to identify factors that might affect the outcome of an experiment. A variable is any factor that can have more than one value. In controlled experiments, there are two kinds of variables. The independent variable is the factor that you want to test. It is changed by the investigator to observe how it affects a dependent variable. The dependent variable is the factor you observe or measure during an experiment. When the independent variable is changed, it causes the dependent variable to change.
**Controlled Experiment** There are two groups in a controlled experiment—an experimental group and a control group. The experimental group is used to study how a change in the independent variable changes the dependent variable. The control group contains the same factors, but the independent variable is not changed. Without a control, it is difficult to know if your experimental observations result from the variable you are testing or from another factor.

**Scientific Inquiry** Scientists used inquiry to investigate the mystery of the Iceman. As you read the rest of the story, notice how scientific inquiry was used throughout the investigation. The scientific inquiry process is shown by the bold text in tables, like the ones below. These tables show what a scientist might have written in a journal.

### Observations, Hypotheses, and Prediction

**Observation:** A corpse was found buried in ice in the Tyrolean Alps.

**Hypothesis:** The corpse found in the Tyrolean Alps is the body of a music professor because he went missing in 1938.

**Observation:** Artifacts found near the body suggested that the body was much older than the music professor would have been.

**Revised Hypothesis:** The corpse found was dead long before 1938 because the artifacts found near him date back way before the 1930s.

**Prediction:** If the artifacts belong to the corpse, then the corpse is not the music professor.

### An Early Conclusion

Konrad Spindler was a professor of archaeology at the University of Innsbruck in Austria when the Iceman was discovered. Spindler estimated that the ax was at least 4,000 years old based on its construction. A few weeks later, however, radiocarbon dating showed that the Iceman had lived about 5,300 years ago.

### Inference and Prediction

**Inference:** Based on its construction, the ax is at least 4,000 years old.

**Prediction:** If the ax is at least 4,000 years old, then the body found near it is also at least 4,000 years old.

**Test Results:** Radiocarbon dating showed the man to be 5,300 years old.

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**Reading Check**

2. Identify What two groups are needed in a controlled experiment?

3. Relate How do scientific investigations often begin?

4. Analyze How did the ax lead to a prediction about the age of the body?
Location of the Iceman  The Iceman’s body was in a mountain glacier 3,210 m above sea level. Just what could this man have been doing so high in the snow- and ice-covered mountains? Was he hunting, was he shepherding his animals, or was he looking for metal ore?

Professor Spindler’s Hypothesis  In 1993, Professor Spindler proposed a hypothesis based partly on the artifacts discovered with the Iceman’s body. For example, he noted some of the wood used in the artifacts was from trees that grew at lower elevations. Spindler concluded that the Iceman was a seasonal visitor to the high mountains.

According to Spindler’s hypothesis, the Iceman had recently driven his herds from their summer high mountain pastures to the lowland valleys. However, after arriving in the lowlands, he chose to return to the mountains. There he died of exposure to the cold, wintry weather.

Professor Spindler observed that the Iceman’s body was extremely well preserved. He inferred that ice and snow covered the Iceman’s body shortly after he died. Spindler concluded that the Iceman died in autumn and was quickly buried and frozen, which preserved his body and all his possessions.

Interpreting Tables

6. State  What steps are necessary before making conclusions?

<table>
<thead>
<tr>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>After many observations, revised hypotheses, and tests, conclusions often can be made.</td>
</tr>
</tbody>
</table>

| Conclusion: The Iceman is about 5,300 years old. He was a seasonal visitor to the high mountains. He died in autumn. When winter came, the Iceman’s body became buried and frozen in the snow, which preserved his body. |

More Observations and Revised Hypotheses

When the Iceman’s body was discovered, Klaus Oeggl was an assistant professor of botany at the University of Innsbruck. His area of study was plant life during prehistoric times in the Alps. He was invited to join the research team studying the Iceman.

Materials at the Discovery Site  Professor Oeggl closely examined the Iceman and his belongings. He found three plant materials—grass from the Iceman’s shoe, a splinter of wood from his longbow, and a tiny sloe berry fruit.
**Examination of the Materials** In the year following the Iceman’s discovery, Professor Oeggl examined bits of charcoal wrapped in maple leaves found at the discovery site. The samples showed that the wood in the charcoal was from eight different types of trees. All but one of the trees grew only at lower elevations than where the Iceman’s body was found.

**A Working Hypothesis** Like Professor Spindler, Professor Oeggl suspected that the Iceman had been at a lower elevation shortly before he died. This idea became his working hypothesis. However, Oeggl would need more data to prove it. He proposed that he be allowed to examine the man’s digestive tract. If all went well, the study would show what the Iceman had swallowed hours before his death.

<table>
<thead>
<tr>
<th>Observations, Hypothesis, and Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Observations:</strong> Plant matter near body to study—grass on shoe, splinter from longbow, sloe berry fruit, charcoal wrapped in maple leaves, wood in charcoal from 8 different trees—7 of 8 types of wood in charcoal grow at lower elevations</td>
</tr>
<tr>
<td><strong>Hypothesis:</strong> The Iceman had recently been at lower elevations before he died because the plants identified near him grow only at lower elevations.</td>
</tr>
<tr>
<td><strong>Prediction:</strong> If the identified plants are found in the digestive tract of the corpse, then the man actually was at lower elevations just before he died.</td>
</tr>
<tr>
<td><strong>Question:</strong> What did the Iceman eat the day before he died?</td>
</tr>
</tbody>
</table>

**Experiment to Test Hypothesis**

The research teams provided Professor Oeggl with a tiny sample from the Iceman’s digestive tract. He was determined to obtain as much information as he could from it. Oeggl carefully planned his scientific inquiry. He needed to work quickly to avoid the decomposition of the sample and to reduce the chances of contaminating the sample.

His plan was to divide the sample into four parts. Each sample would undergo several chemical tests. Then, the samples would be examined under an electron microscope. Professor Oeggl added several drops of saline solution to the first sample, causing it to swell. He then examined it under the microscope at low magnification. He saw a type of grain known as einkorn. This had been a common type of wheat grown in the region during prehistoric times. He also found other edible plant material.

**Reading Check**

8. Explain Why did Professor Oeggl want to study the Iceman’s digestive tract?

Interpreting Tables

9. Evaluate How did the observations about plant matter influence the hypothesis?

**Reading Check**

10. Define What is einkorn?
Test a Hypothesis

There is more than one way to test a hypothesis. Scientists might gather and evaluate evidence, collect data and record their observations, create a model, or design and perform an experiment. They also might perform a combination of these skills.

Test Plan:
• Divide a sample of the Iceman’s digestive tract into four sections.
• Examine the pieces under microscopes.
• Gather data from observations of the pieces and record observations.

Variables

Controlled experiments contain two types of variables.

Dependent Variables: amount of hop-hornbeam pollen grains found on slide

Independent Variable: digestive-tract sample

The sample also contained pollen grains. To see the pollen grains better, Professor Oeggl used a chemical that would separate unwanted substances from the pollen grains. He applied some alcohol to the sample and examined it under a microscope at a higher magnification. The pollen grains were more visible. Many more microscopic pollen grains could now be seen. Professor Oeggl identified these pollen grains as those from a hop-hornbeam tree.

Analyzing Results

Professor Oeggl observed that the hop-hornbeam pollen grains had not been digested. Therefore, the Iceman must have swallowed them within hours before his death. But, hop-hornbeam trees only grow in lower valleys. Oeggl was confused. How could pollen grains from trees at low elevations be ingested within a few hours of this man dying in high, snow-covered mountains? Professor Oeggl suspected his sample might be contaminated. Oeggl knew he needed to investigate further.

Further Experimentation

Oeggl realized that the most likely source of contamination would be his own laboratory. He decided to test whether his lab equipment or saline solution contained the hop-hornbeam pollen grains.

Sample Slides To do this, he prepared two identical, sterile slides with saline solution. Then, on one slide, he placed a sample from the Iceman’s digestive tract. The slide with the sample was the experimental group. The slide without the sample was the control group.
Variables The independent variable, or the variable that Oeggl changed, is the presence of the sample on the slide. The dependent variable, or the variable that Oeggl was testing, was whether hop-hornbeam pollen grains show up on the slides. Oeggl examined the slides carefully.

Analyzing Additional Results
The experiment showed that the control group (the slide without the digestive tract sample) contained no hop-hornbeam pollen grains. Therefore, the pollen grains had not come from his lab equipment or solutions. Each sample from the Iceman’s digestive tract was closely re-examined. All of the samples contained the same hop-hornbeam pollen grains. The iceman had indeed swallowed the hop-hornbeam pollen grains.

Managing Error
Error is common in scientific research. Scientists are careful to document procedures and any unanticipated factors or accidents. They also are careful to document uncertainty in their measurements.

Procedure:
• Sterilize laboratory equipment.
• Prepare saline slides.
• View saline slides under electron microscope.
Results: no hop-hornbeam pollen grains
• Add digestive tract sample to one slide.
• View this slide under electron microscope.
Result: hop-hornbeam pollen grains present

Control Group
Without a control group, it is difficult to determine the origin of some observations.

Control Group: sterilized slide

Experimental Group: sterilized slide with digestive tract sample

Mapping the Iceman’s Journey
The hop-hornbeam pollen grains were helpful in determining the season the Iceman died. Because the pollen grains were whole, Professor Oeggl inferred that the Iceman swallowed the hop-hornbeam pollen grains during their blooming season. Therefore, the Iceman must have died between March and June.

Reading Check
14. State What did the professor conclude based on the control slide?

15. Summarize How do scientists manage error in their research?

Reading Check
16. Point Out Why did Professor Oeggl believe the Iceman died in spring?
**Additional Study and Investigation** Professor Oegg1 was ready to map the Iceman’s final trek up the mountain. Because Oegg1 knew the rate at which food travels through the digestive system, Oegg1 inferred that the Iceman had eaten three times in the final day-and-a-half of his life. From the digestive tract samples, Oegg1 estimated where the Iceman was when he ate.

**Final Hours** First, the Iceman ingested pollen grains native to higher mountain regions. Then he swallowed hop-hornbeam pollen grains from the lower mountain regions several hours later. Last, the Iceman swallowed other pollen grains from trees of higher mountain areas again. Oegg1 proposed the Iceman traveled from the southern region of the Italian Alps to the higher, northern region as shown in the figure below. There he died suddenly. He did this all in a period of about 33 hours.

**Reading Check**

17. **Summarize** What was Professor Oegg1 able to determine about the Iceman’s movements from the different types of pollen residue?

18. **Draw** Highlight the possible route of the Iceman. Circle the place where he was found near the border of Austria and Italy.
Observation, Inference, and Prediction

An inference is a logical explanation of an observation that is drawn from prior knowledge or experience. Inferences can lead to predictions, hypotheses, or conclusions.

| Observation: | The Iceman’s digestive tract contains pollen grains from the hop-hornbeam tree and other plants that bloom in spring. |
| Inference: | Knowing the rate at which food and pollen decompose after they are swallowed, it can be inferred that the Iceman ate three times on the day that he died. |
| Prediction: | The Iceman died in the spring within hours of digesting the hop-hornbeam pollen grains. |

Conclusion

Researchers from around the world worked on different parts of the Iceman mystery and shared their results. Analysis of the Iceman’s hair revealed his diet usually contained vegetables and meat. Examining the Iceman’s one remaining fingernail, scientists determined that he had been sick three times within the last six months of his life. X-rays revealed an arrowhead under the Iceman’s left shoulder. This suggested that he died from that serious injury rather than from exposure.

Finally, scientists concluded that the Iceman traveled from the high alpine region in spring to his native village in the lowland valleys. There, during a conflict, the Iceman sustained a fatal injury. He retreated back to the higher elevations, where he died. Scientists recognize their hypotheses can never be proved, only supported or not supported. However, with advances in technology, scientists are able to more thoroughly investigate mysteries of nature.

Revised Conclusion

Scientific investigations may disprove early hypotheses or conclusions. However, new information can cause a hypothesis or conclusion to be revised many times.

Revised Conclusion: In spring, the Iceman traveled from the high country to the valleys. After he was involved in a violent confrontation, he climbed the mountains into a region of permanent ice where he died of his wounds.

Interpreting Tables

19. Define What is an inference?

20. Describe the new evidence that led to a conclusion about why the Iceman died.

21. Explain Why might a hypothesis or conclusion be revised?
Mini Glossary

**dependent variable:** the factor an investigator observes or measures during an experiment

**independent variable:** the factor that is changed by the investigator to observe how it affects a dependent variable

**variable:** any factor that can have more than one value

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes the relationship between an independent variable and a dependent variable.

2. Write the words below in the correct boxes in the flowchart to summarize the steps used in this case study.

   - observations
   - conclusion
   - tests
   - prediction
   - hypothesis
   - analysis

3. Explain how making an outline helped you understand this lesson.