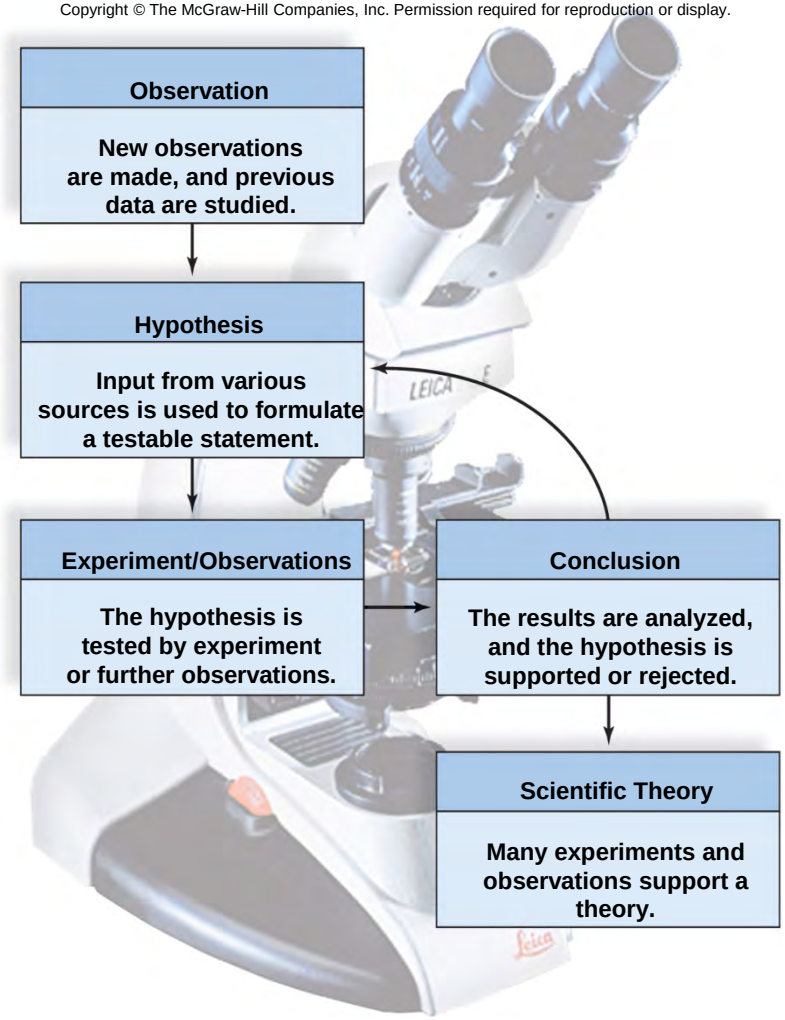
The Scientific Method

- Scientific method is a standard series of steps in gaining new knowledge through research.
  - Begins with **observation**
    - Scientists use their five senses e.g. use visual sense to observe animal behavior
    - Instruments can extend the range of senses e.g. use microscope to see microorganisms
    - Take advantage of prior studies
  - **Hypothesis**
    - A tentative explanation for what was observed
    - Developed through inductively reasoning from specific to general

The Scientific Method: A Flow Diagram



Courtesy Leica Microsystems Inc.

The Scientific Method: Experimentation

- **Experimentation**
  - Purpose is to challenge the hypothesis
  - Designed through deductively reasoning from general to specific
  - Often divides subjects into a **control group** and an **experimental group**
  - **Predicts** how groups should differ if hypothesis is valid
    - If prediction happens, hypothesis is unchallenged
    - If not, hypothesis is unsupportable

The Scientific Method

- The results are **analyzed** and **interpreted**
- **Conclusions** are what the scientist thinks caused the results
- Findings must be reported in scientific journals
- **Peers review** the findings and the conclusions
- Other scientists then attempt to **duplicate** or **dismiss** the published findings

The Scientific Method: Results

- **Results or Data**
  - Observable, objective results from an experiment
  - Strength of the data expressed in probabilities
  - The probability that random variation could have caused the results
    - Low probability (less than 5%) is good
    - Higher probabilities make it difficult to dismiss random chance as the sole cause of the results

Scientific Theory

- **Scientific Theory:**
  - Joins together two or more related hypotheses
  - Supported by broad range of observations, experiments, and data
- **Scientific Principle / Law:**
  - Widely accepted set of theories
  - No serious challenges to validity

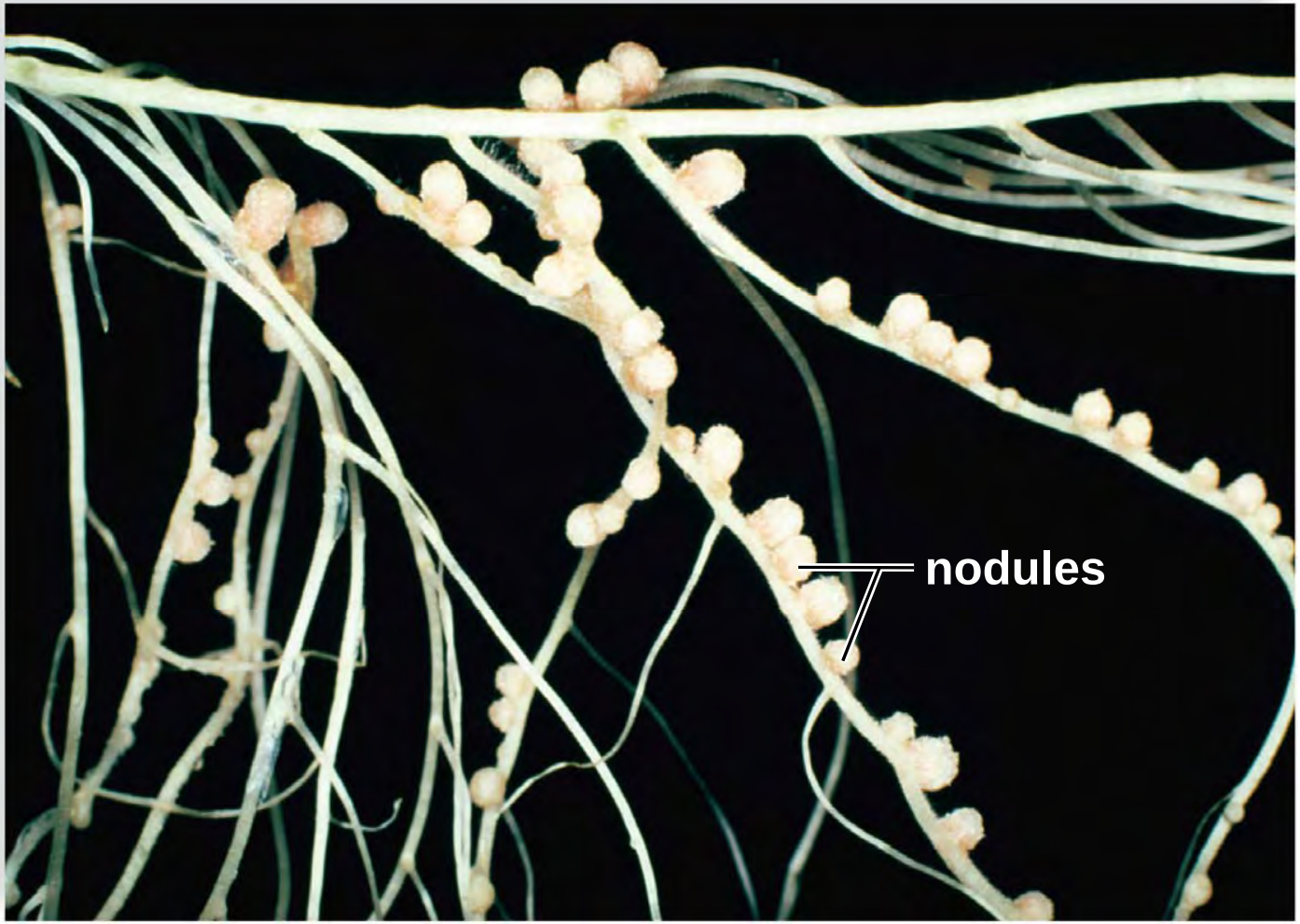
Controlled Experiments

- Experimental **(Independent**) variable
  - Applied one way to experimental group
  - Applied a different way to control group
- Response (**dependent**) variable
  - Variable that is measured to generate data
  - Expected to yield different results in control versus experimental group

Controlled Experiments

- Observations:
  - Nitrate fertilizers boost grain crops, but may damage soils by altering its properties
  - When grain crops are rotated with pigeon pea it adds natural nitrogen
- Hypothesis:
  - Pigeon pea rotation will boost crop production as much as nitrates
  - Pigeon pea rotation will NOT damage soils

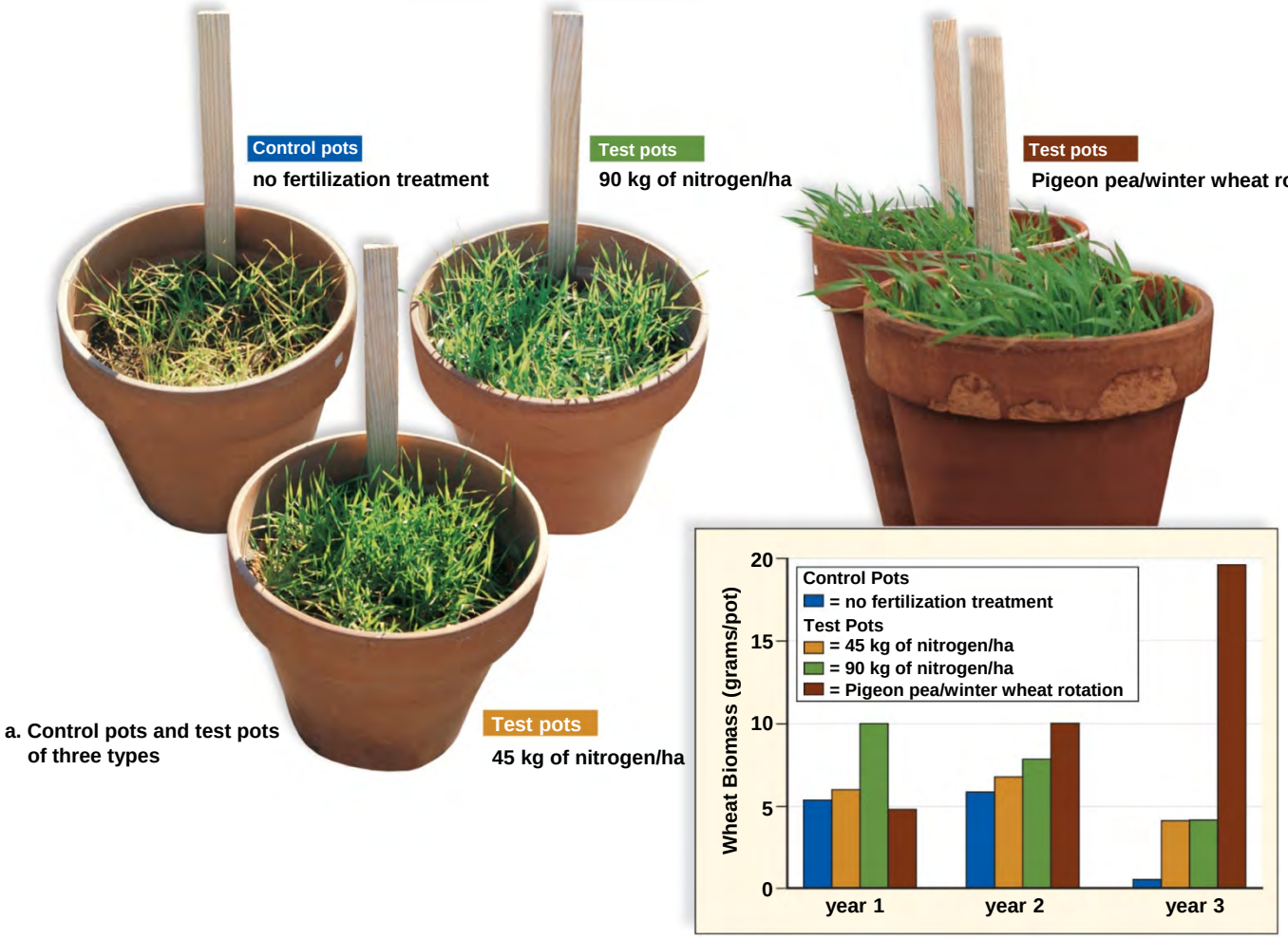
Root Nodules



Controlled Experiments

- Experimental Design
  - Control Group
    - Winter wheat planted in pots without fertilizer
  - Experimental Groups
    - 1-Winter wheat planted in pots with 45 kg/ha nitrate
    - 2-Winter wheat planted in pots with 90 kg/ha nitrate
    - 3-Winter wheat planted in pots that had grown a crop of pigeon peas
  - All groups treated identically except for above

Crop Rotation Study



a. Control pots and test pots of three types

b. Results

(All): Courtesy Jim Bidlack

Controlled Experiments

- Experimental Prediction:
  - Wheat production following pigeon pea rotation will be equal or better than following nitrate fertilizer
- Results
  - 45 kg/ha produced slightly better than controls
  - 90 kg/ha produced nearly twice as much as controls
  - Pigeon pea rotation did not produce as much as the controls

Controlled Experiments

- Conclusion
  - Research hypothesis was not supported by results
  - However, research hypothesis was not proven false by negative results
- Revised experiment
  - Grow wheat in same pots for several generations
  - Look for soil damage in nitrate pots and improved production in pigeon pea pots

Controlled Experiments

- Results
  - After second year:
    - Production following nitrates declined
    - Production following pigeon pea rotation was greatest of all
  - After third year
    - Pigeon pea rotation produced 4X as much as controls
- Revised conclusions
  - Research hypothesis supported
  - Pigeon pea rotation should be recommended over nitrates