THE SCIENTIFIC METHOD
(to the tune of “Dixie”)
Lyrics by Doug Eldon ©

Oh, what do you think a scientist does
To solve a problem found because
Many scientists are scientists
‘Cause they’re great problem solvers

There is a systematic way
They go about ‘most every day
It’s methodical and it’s logical
The scientific method

Chorus: A way to solve a problem, a way, a way
The scientific method is a way to solve a problem
A way, a way, a way to solve a problem
A way, a way, a way to solve a problem

It may not seem important to you
But the first thing that they always do
Is state the problem or ask a question
So they know just what they’re after

Then they review everything involved
That might help get the problem solved
By reading, researching
And gathering information

Chorus:

After both of these steps they take
They go ahead and then they make
An educated guess—a hypothesis—
A possible solution

Then they use scientific tools
To measure and test some variables
In experiments which are really meant
To give more information

Chorus:

This information they call data
They put together so that later
They can analyze and synthesize
To see just what it all means

Only when they have done all these
Experiments testing hypotheses
Which may prove, or else disprove
Then they’ll state their conclusion

Chorus:

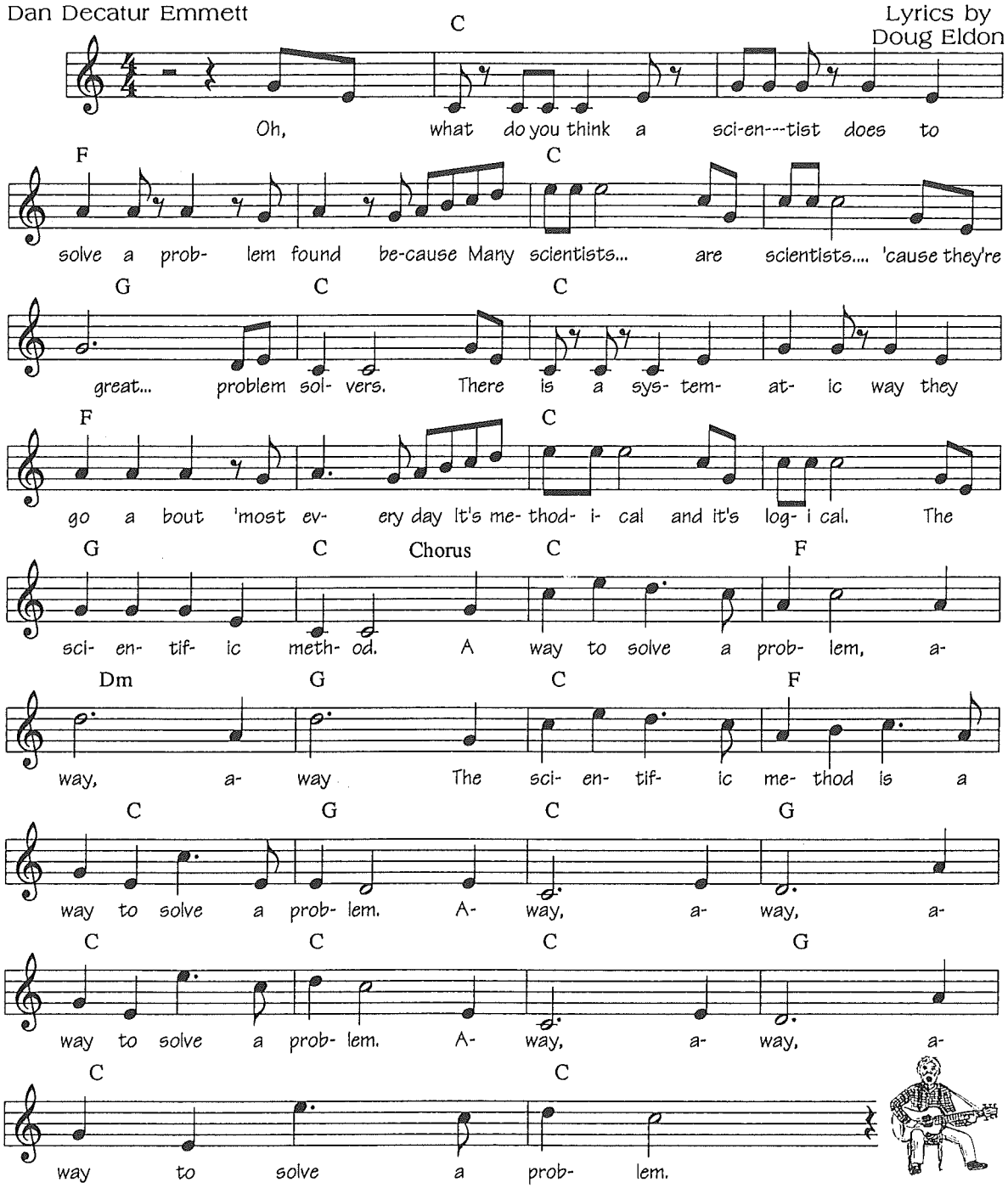
This is the systematic way
A scientist may use any old day
‘Cause it’s methodical and it’s logical
The scientific method

THE SCIENTIFIC METHOD

(to the tune of "Dixie")

Dan Decatur Emmett

Lyrics by Doug Eldon



It may not seem important to you but the first thing that they always do
Is state the problem or ask a question so they know just what they're after
Then they review everything involved that might help get the problem solved
By reading, researching and gathering information

After both of these steps they take they go ahead and then they make
An educated guess; a hypothesis; a possible solution
Then they use scientific tools to measure and test some variables
In experiments which are really meant to give more information

This information they call data, they put together so that later
They can analyze and synthesize, to see just what it all means
Only when they have done all these experiments testing hypotheses
Which may prove or else disprove, then they'll state their conclusion.

This is the systematic way a scientist may use any old day
'Cause it's methodical and it's logical the scientific method.

THE SCIENTIFIC METHOD

Dr. Karen Timm is a scientist by profession who is in this book to help with the scientific information. Specifically, she is a veterinary professor and a specialist in laboratory animal medicine. She enjoys her subject so much that she raises Macaws, a species of beautiful tropical birds.

Doug Eldon is a teacher who enjoys life science almost every day. When he's not in his classroom, he raises silkworms, grows fungi and explores creeks and woods searching for insects and unusual plants. He joins Dr. Timm and adventures throughout the scientific information to show you, the reader, that life science can be very interesting and exciting.

The word **science** means to have knowledge of, or to know. It also means the organized system of knowledge that comes from observation, study and experimentation.

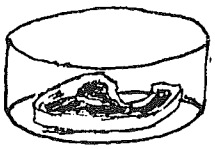
Many scientists spend their time making observations, asking questions and finding problems to solve. In fact, part of the reason they are scientists is that they are good at problem solving and enjoy the challenge of figuring things out. They study and think about what is known and what needs to be learned. Then they may experiment, and use the information gained to answer the question or solve the problem they have. This whole process has been called the **scientific method**.

If you study any particular field or branch of science, you will find that there are facts, principles (rules) and methods (ways of doing things). There are also many words or terms that help scientists communicate what they know. One aspect of understanding science is learning the vocabulary; another is learning the systems for organizing information; and still another part is learning to think and to solve problems the scientific way!

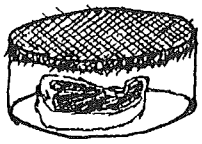
A systematic way of doing things is organized and purposeful; it is methodical if it involves orderly steps; and it is logical if it is reasonable, makes sense and is well thought out beforehand. The scientific method combines all of these aspects.

Six steps often included in the scientific method are:

1 - Ask a question or state the problem
2 - Gather information
3 - Make a hypothesis
4 - Experiment
5 - Analyze data
6 - State a conclusion



THE SCIENTIFIC METHOD IN USE



Meat in covered container was not exposed to flies— no maggots appeared

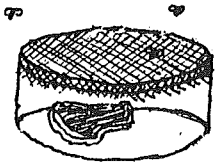
To demonstrate how the scientific method can be used, let's go back to the 1860's when a French scientist named Louis Pasteur was trying to solve one of the most basic questions in the study of life: Where do living things come from?

We know now that living things come from other living things but scientists in earlier times didn't have the knowledge or understanding about how things came to be. Their explanation often was that life occurred all by itself. Nonliving matter was thought to produce living things: frogs were thought to come from the mud of riverbanks, beetles from dung and maggots from decaying meat! This simple explanation became known as the theory of **spontaneous generation**.

Meat in open container was exposed to flies— maggots appeared on the meat

Step 1 - Ask a Question or State the Problem

For Pasteur the question was: Do living things come alive spontaneously, or do they all come from parents of the same kind? He was at the time working with microscopic organisms, and so his specific question was: Do germs just appear from nowhere?

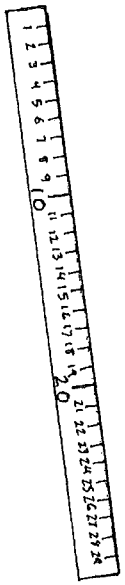


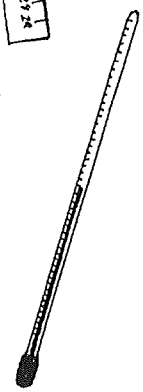
Step 2 - Gather Information

Pasteur studied the works of other scientists. He read of the experiment an Italian biologist named Redi had done in 1668 that proved that maggots did not come from meat. If flies were kept off the meat by covering it, the fly eggs could not be laid and maggots did not appear. Pasteur learned from this experiment that Redi convinced scientists that complex creatures came only from others like themselves. But what about microscopic forms of life?

The microscope was first developed and used to see tiny organisms in the early 1700's but it was not until about 1760 that another Italian biologist named Spallanzani seriously began to study microorganisms. Pasteur read of his experiments which showed that microscopic organisms, or **microbes**, did not come to life spontaneously, but were often carried by dust in the air. Spallanzani also discovered that microbes reproduced by dividing, and were killed by boiling.

Scientists use metric tools when conducting experiments





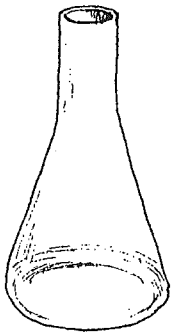
Step 3 - Make a Hypothesis

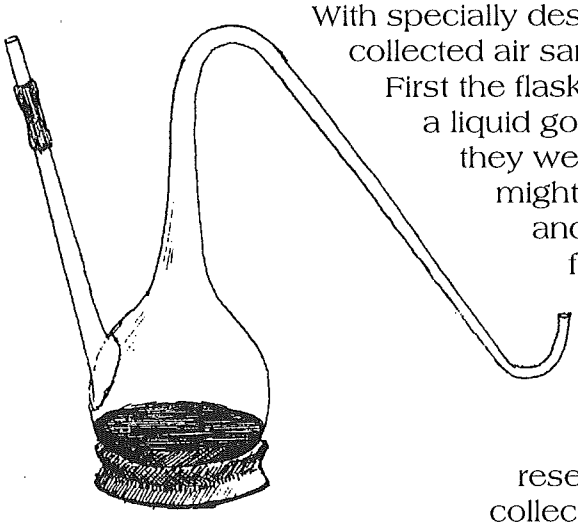
Pasteur used what he learned from Spallanzani and Redi and what he knew from his own experiments to form a **hypothesis** (a possible answer to his question). He basically restated much of what Spallanzani had said one hundred years earlier. That was:

1 - living things come from other living things of the same kind.
2 - some are too small to be seen without a microscope.
3 - they are spread by floating on dust in the air.

Step 4 - Experiment

Spallanzani conducted an experiment which involved boiling a liquid in a glass flask, then sealing it. He found that microbes did not appear in the closed flask, but grew in an open one. He concluded from this experiment that microbes are in the air and boiling kills them. Other scientists still argued that the boiling changed the conditions needed for spontaneous generation to occur and closing the flasks kept oxygen out, which the microbes needed to live and grow. Factors that might affect the results of an experiment are called **variables**. Pasteur had to design an experiment where he could control all the variables in order to prove that microbes indeed were carried on dust in the air, and did not just appear.





Pasteur's swan-neck flask

With specially designed glass flasks, Pasteur collected air samples from different places. First the flasks were carefully prepared with a liquid good for growing microbes. Then they were heated to kill anything that might have been living in the liquid and were sealed. He collected air from a busy city street, a garden yard, a quiet cellar, a nearby hill and a high mountain glacier. He did this by opening the flasks for an instant to let air in, then quickly resealing them. At each location he collected ten to twenty flasks of air. Then he waited to see what would grow.

Step 5 - Analyze Data

Pasteur could have recorded his data in a table such as this:

Location of air sample	Number of flasks	Number with microbes
city street	10	10
garden yard	11	11
quiet cellar	10	1
nearby hill	20	8
high mountain	20	1

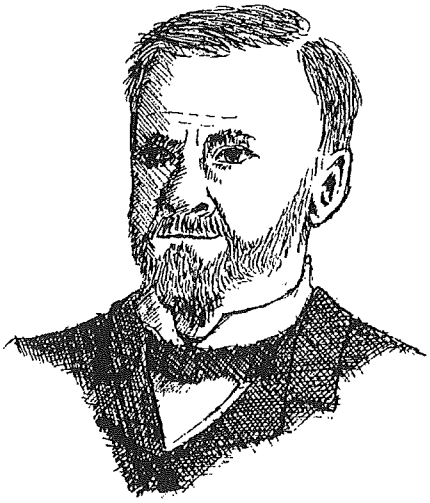
By **synthesizing** or putting together his data, Pasteur could clearly see his results. Pasteur reasoned that the air from the city and the yard both had a lot of microbe-carrying dust, but that the air from the cellar was quite still, with little dust. He further reasoned that the air in higher elevations had less and less dust and therefore fewer and fewer microbes.

Step 6 - State a Conclusion

Pasteur learned from experiments others had done; he made a hypothesis; he then performed his own experiments, controlling the variables; and he analyzed the data he gathered. He could now conclude that the dust in the air carried microbes and they did not just appear but come from other microbes of the same kind.

Although the scientific method was not something formally taught or learned by Pasteur, it was the process he used. Scientists continue to use this approach to solve modern scientific problems.

Many scientists still argued for spontaneous generation. After many years of repeating his experiments, Pasteur finally convinced the scientific world that he was right! As you will see in the chapters on viruses, bacteria and protozoa, what became known as the **germ theory** changed science and medicine in many ways.



LOUIS PASTEUR
1822-1895

THE SCIENTIFIC METHOD - Lyrics

Oh, what do you think a_____ does
To solve a _____ found because
Many _____ are scientists
'Cause they're great_____ solvers
There is a_____ way

They go about 'most every day
It's _____ and it's _____
The _____ method

Chorus: A way to_____ a problem, a way, a way
The_____ _____ is a way to solve a _____
A way, a way, a way to _____ a problem
A way, a way, a way to solve a _____

It may not seem important to you
But the _____ thing that they always do
Is state the _____ or ask a _____
So they know just what they're after
Then they _____ everything involved
That might help get the _____ solved
By reading, _____
And gathering _____
Chorus

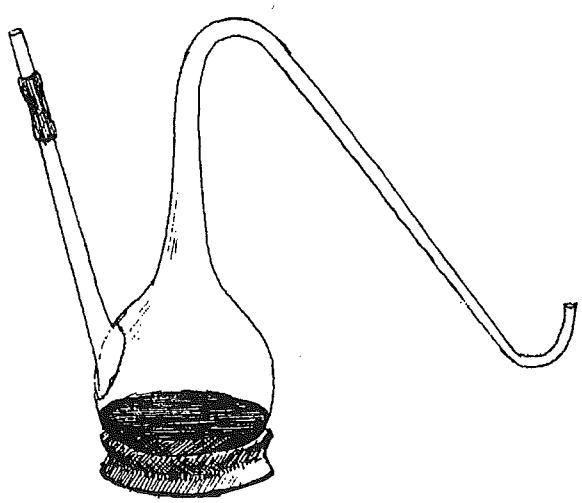
After both of these _____ they take
They go ahead and then they make
An educated guess—a _____—
A possible _____
Then they use _____ tools
To _____ and test some variables
In _____ which are really meant
To give more _____
Chorus

This information they call _____
They put together so that later
They can analyze and _____
To see just what it all means
Only when they have done all these
_____ testing _____
Which may prove, or else _____
Then they'll state their _____
Chorus

This is the_____ way
A _____ may use any old day
'Cause it's _____ and it's logical
The _____ _____

Fill in the blanks, you may use words more than once.

conclusion
data
disprove
experiments
first
hypotheses
hypothesis
information
logical
measure
method
methodical
problem
question
researching
review
scientific
scientist
scientists
solution
solve
steps
synthesize
systematic



THE SCIENTIFIC METHOD - Objective

True or false

1 - _____ Pasteur proved that germs are carried in the air.
2 - _____ Microbes can be easily seen.
3 - _____ A variable does not change the outcome of an experiment.
4 - _____ Microscopes were first used in the early 1900's.
5 - _____ A hypothesis is a possible answer to a problem.

Matching

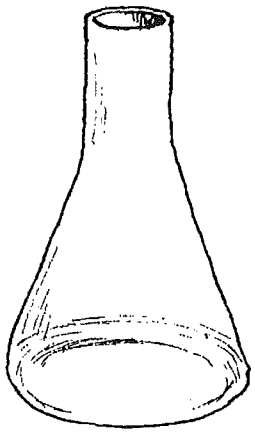
6 - Pasteur _____	A. Following orderly steps
7 - methodical _____	B. Discovered that microbes were killed by boiling
8 - variables _____	C. An educated guess, a possible solution
9 - Spallanzani _____	D. Factors that may affect the result of an experiment
10 - hypothesis _____	E. Proved microbes were carried on dust in the air

List the six steps of the scientific method in proper order:

11 - _____ Analyze data
12 - _____ Gather information
13 - _____ State a conclusion
14 - _____ Ask a question or state the problem
15 - _____ Experiment
16 - _____ Make a hypothesis

Fill in the blank

17 - A hypothesis can be tested by conducting _____.
18 - A hypothesis is an educated guess or a _____ _____.
19 - The information collected during experiments is often called _____.
20 - A _____ is stated after data is analyzed.



THE SCIENTIFIC METHOD - Essay

1 - Compare step one of the scientific method (ask a question or state the problem) with solving a math story problem. _____

_____

_____

_____

_____

2 - Why is it important to gather information by reviewing, reading and researching?

_____

_____

_____

3 - Why is it important to control variables in an experiment? _____

_____

_____

_____

4 - Why is it important to follow the steps of the scientific method in order?

_____

_____

_____

_____

5 - What can be done with data to make it easier to analyze? _____

_____

DIGGING DEEPER

1 - Scientists might not be able to prove that their hypothesis was correct. Why is it important for scientists to be willing to admit that their educated guess was wrong, even after all the work they did?_____

_____

_____

_____

_____

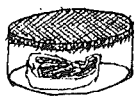
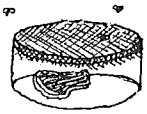
_____

2 - If a hypothesis is a possible explanation or solution, what is a theory and what is a law?

THEORY:_____

_____

LAW: _____

_____

_____