

ARTICLE

# Henry David Thoreau, Forest Succession & The Nature of Science: A Method for Curriculum Development

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A main reason for using the history of science in classroom instruction is its utility in promoting students' understanding of the nature of science (hereafter NOS). As indicated in such documents as the *National Science Education Standards*, it is important to help students develop their understanding of NOS so that they will become more critical consumers of the very scientific knowledge that increasingly impacts their daily lives (National Research Council, 1996).

Science education research draws attention to the importance of having students *explicitly* and *reflectively* consider NOS tenets during instruction (Howe & Rudge, 2005; Khisfhe & Abd-El-Khalick, 2002). Explicit learning means that through some aspect of instruction, one or more of the relevant NOS tenets are directly targeted for students to evaluate. Reflective learning underscores that students must be challenged to develop their own conceptual understanding of the NOS tenets, in contrast to the alternative (didactic) approach in which a teacher "tells" students how the NOS tenet applies to a given situation.

Another important consideration for NOS instruction is the degree to which it is imbedded in a context (Clough, 2006). On one end of the spectrum, there are decontextual approaches which involve exposing students to various "black box" activities (Lederman & Abd-El-Khalick, 1998) and having them explicitly/reflectively examine relevant NOS tenets. These can be very powerful introductions to NOS, but as Clough (2006) points out, when students only learn such tenets in a decontextual approach, they may leave instruction with a dualistic conception of NOS – believing that what occurs in "real science" is distinct from that learned during the decontextual activity.

Using history of science in instruction is a potential contextual approach for students to explicitly and reflectively learn NOS tenets, and science education literature contains numerous examples of its use in this regard (e.g., Howe, 2007; Monk & Osborne, 1997; Khisfhe & Abd-El-Khalick, 2002; Solomon, Duveen, Scot & McCarthy, 1992). Indeed, these studies provide empirical efficacy (albeit modest) that the instrumental use of history of science can help students develop more informed NOS conceptions. While these studies effectively present varied ways that history has been used in this regard, they do not provide sufficient detail for teachers to replicate their approaches (how to go about identifying and connecting relevant aspects of the history of science to the important NOS tenets).

This article provides a method for teachers who intend to use one or more epi-

sodes from the history of science to help their students explicitly and reflectively learn more informed NOS conceptions. The method facilitates:

1. how to identify relevant NOS tenets exemplified in the episode.
2. how to design classroom problems that have students explicitly and reflectively consider NOS using the historical episode.

An example of this approach is given using the work of Henry David Thoreau and introductory concepts of ecological forest succession. Though several of the specific elements of the Thoreau lessons are discussed in the next sections, for the sake of space, only the salient features are highlighted. Readers are certainly encouraged to download supplemental materials from the author, which include the lesson plans and a detailed discussion of how to go about researching episodes from the history of science for use in the classroom. These can be found at <http://www.assumption.edu/users/emhowe/Thoreau.html>.

## ○ The Nature of Science

Essentially, NOS deals with understanding the unique aspects of scientific knowledge or scientific ways of knowing. Stakeholders in science education largely agree that there are fundamental tenets about NOS that students should be learning in the classroom (McComas, 2005). A partial list of these tenets underscores that:

- Science demands and relies on empirical evidence.
- Knowledge production in science shares common methods and shared habits of mind, norms, logical thinking, and methods (such as careful observation and data recording, truthfulness in reporting, etc.).
  - Experiments are not the only route to knowledge.
  - Explanations in science (hypotheses and theories) provide a means for prediction.
  - Science uses both inductive reasoning and hypothetico-deductive testing.
  - However, there is no one-step scientific method by which all science is done.
- Scientific knowledge is tentative, durable, and self-correcting (meaning that science cannot definitively prove anything, but scientific conclusions are still valuable and long-lasting because of the way in which they are developed).
- Science has a subjective component (theory-laden character).
- Science has a creative component.
- There are historical, cultural, and social influences on the practice of science.

*... it is important to help students develop their understanding of the nature of science so that they will become more critical consumers of the very scientific knowledge that increasingly impacts their daily lives.*

## ○ Phase I: Researching Henry David Thoreau & Forest Succession

For my introductory college biology course, I was particularly interested in having students learn about fundamental community ecology concepts (e.g., competition, resources, biotic and abiotic factors, dispersion, succession) with reference to the topic of forest succession. I was also interested in having students develop their understanding of aspects of NOS through the use of any history of scientific work on ecological succession. My first “phase” of research involved my having to identify an episode in the history of science (in this case, the work of Henry David Thoreau) and my having to learn enough of the general and specific philosophical details of the historical “story” and its actors to understand how I might use the episode in the classroom. This phase is detailed in the supplemental downloadable materials for those interested in doing historical research.

From this research, the following “picture” began to emerge: Henry David Thoreau maintained an acute interest in natural history of his native countryside in central New England throughout his relatively brief life. Part of his passion for natural history stemmed from his affinity for the transcendental movement and the romantic philosophies – whose followers believed in the importance of countering the increasing exploitation of the environment. They held central beliefs that nature was capable of renewal and revitalization and that living organisms (of which humans played only a part) were bound together in an almost spiritual and metaphysical interrelationship (Bowler & Morus, 2005; Worster, 1994). In addition, Thoreau’s burgeoning interest in the systematic study of nature stemmed from his evident commitment to a mechanistic philosophy – a philosophy linked closely to the methods developed from the Scientific Revolution (Whitford, 1950, 1951).

Well before Thoreau’s time, the work of Newton, Descartes, Galileo, Kepler, and others in the physical sciences during the 16th and 17th centuries collectively created what has come to be known as the mechanistic philosophy for studying the physical realm, namely that all physical entities (including living organisms) were analogous to machines, and as such, scientists should explain their behavior strictly in terms of mechanical interactions among their parts. This contrasts with previous understandings of the natural world, which often made reference to mystical or metaphysical considerations to account for natural phenomena.

Thoreau’s writings reveal that his interest in natural history was motivated by two ironically conflicting philosophical commitments. His holistic feelings about nature reflected the ideals of the Romantic Movement: He was passionately committed to environmental conservation because he witnessed firsthand the reduction of forests and environment in and around his native home, and he was inspired by early holistic writers of nature (e.g., Gilbert White of Selbourne, England). His writings reveal a holistic worldview which seeks to understand how everything in nature interacts almost purposefully to produce a harmonious and self-sustaining whole. Yet his scientific observations drew from his interest in the mechanistic philosophy and inductive approaches to studying nature. Here, his writings support his interest in the systematic observational analysis of the interrelationships of living things. This is reflected in the amount of time he spent observing and recording the life history of various plants (termed phenology) in and around central Massachusetts. This work he placed in a series of *Journals* from the period of approximately 1845 to 1860.

The Whitford articles and Thoreau’s writings (1906a, 1993) revealed that Thoreau was particularly interested in studying a

curious problem related to the succession of wood (forest) lots. Because he was well known in his community as a naturalist, Thoreau’s advice on various issues was periodically sought, and it is apparent from his writings that he was often called upon by local farmers to resolve how tree species replaced one another in certain forest stands. I subsequently refer to this as the “Farmers’ Problem.”

### The “Farmers’ Problem”

In the mid 19th century a significant proportion of manufactured goods were made from wood and, because of this, forestry (forest management) had become an important industry in New England. Farmers were vitally interested in understanding how to properly raise, cultivate, harvest, and, most importantly, maintain forest stands. Around the time of the 1850s, farmers in Concord, Massachusetts, kept asking why, when they cut off a stand of lumber in a particular lot of forest, it would often “come back” as an entirely different species of tree. For example, cut hardwood (e.g., oak) in a woodlot would be replaced by pitch pine (e.g., white pine), and when farmers cut a pine stand, the same ground came up later as hardwood.

Whitford (1950) gives a nice summary of several of the prevailing explanations that Thoreau’s contemporaries held to account for the emergence of new tree species (Table 1), including the belief that new species were the result of divine intervention, having arisen from special creation or spontaneous generation. Table 1 presents a summary of the various explanations, including Thoreau’s ultimate claim that tree succession in the Farmers’ Problem resulted primarily from differential seed dispersal, germination, and seedling survival. The table also summarizes the evidence presented in the Whitford article and from Thoreau’s own writings (1906a) which either support or refute the various explanations to account for the replacement of tree species in the Farmers’ Problem.

What is particularly noteworthy of Thoreau’s approach to the problem is his use of a careful systematic method to understand how new species could arise. He gathered data on the various species of deciduous and coniferous trees that existed in relation to the sites of succession. He studied the methods (and rates) of seed dispersal, the germination of seeds, the conditional survival of seedlings, and the habitats and foraging characteristics of various woodland birds and rodents. From this corpus of data, he was able to propose his provisional theory to account for the Farmers’ Problem (owing to differences in seed dispersal and germination), and he was also able to refute many of the prevailing explanations that relied upon faith or tenuous conjecture.

## ○ Phase II: Identifying Germane NOS Tenets

Though decontextual lists of NOS similar to that presented earlier in this article are certainly important for drawing attention to the multifaceted character of NOS, they alone are not conducive for teachers who want to develop curriculum that infuses NOS instruction into the lessons. This is because the tenets as given do not explicitly help teachers link the conceptual material that they intend to use in the classroom with the relevant aspects of NOS.

For this reason, teachers would benefit from thinking about potential NOS instruction not in terms of tenets, but in terms of NOS guiding questions (Clough, 2006b; Howe, 2007). Specific to the work of Thoreau, I used many of these guiding NOS questions when I considered how Thoreau and his contemporaries sought to solve the Farmers’ Problem, particularly the explanations they proposed and the evidence they relied upon or methods they used to bear upon the problem. Using guiding NOS questions in this way

**Table 1. Explanations of the Farmers' Problem**

Tree species succeed (or arise) because:	
Explanation	Evidence in Support or Against
Spontaneous Generation (The Divine Creation of Replacement Species)	<ul style="list-style-type: none"> <li>This was believed by many of Thoreau's contemporaries.</li> <li>Aligned with a belief in divine creation of species.</li> <li>Thoreau explicitly indicates in his writing (<i>Journals</i>) that he sees no evidence to support this.</li> <li>Thoreau points out how non-native trees in New England could not simply "arise" from nowhere but rather must have been brought to America from the outside.</li> </ul>
Seeds Lie in Ground For Many Years and Await Favorable Conditions for Germination	<ul style="list-style-type: none"> <li>Thoreau gathered acorns of oaks and placed them in a drawer for six months. Subsequent germination was poor.</li> <li>For oaks, he either had to accept that seeds could lie dormant in the ground or come up with another explanation for their distribution.</li> </ul>
Stump Sprouts Around Recently-Cut Trees Must Produce New Growth	<ul style="list-style-type: none"> <li>This would not explain succession of one species to or by another.</li> <li>Thoreau points out that sprout regeneration actually makes for a weaker tree.</li> </ul>
Seed Dispersal and Germination (Thoreau's Explanation)	<ul style="list-style-type: none"> <li>Thoreau drew an analogy to pine and maple seeds in relation to their being carried on the wind.</li> <li>He made extensive observations of the behavior of squirrels and their foraging for nuts, noting the tendency of squirrels to take the heavy nuts of oaks great distances.</li> <li>Thoreau observed oak seedlings in mature pine forests and noted that they were seemingly shade tolerant as seedlings.</li> </ul>

was also very helpful when I made the transition to thinking about ways of promoting students to explicitly consider NOS tenets in connection with their examining the conceptual problems. I used many of the specific questions (Table 2) during my curriculum development, but I altered them below to a form more conducive for students to use as NOS probes to consider during instruction (discussed in the next section).

**NOS Tenet: Empirical Nature of Science – Scientists Gather Data Through Their Sensory Observations/ Input**

- *Is Thoreau's approach scientific? Why or why not?*
- *What actions (or methods) did Thoreau use that you feel characterize him as scientific? Are there any that do not?*

Part of what embodies a scientific approach is that it relies on empirically-derived data. Thoreau made specific observations of the behavior of various tree species (their lifecycles) and the behavior of various forest inhabitants (e.g., rodents, squirrels). Using specific data, Thoreau deduced that the most fruitful explanation was that the mechanism for tree succession related to the reproductive methods of seed dispersal, germination, and competition for resources.

Thoreau also believed in Linnaeus' claims of organismal hierarchies, which in today's interpretive lens

is seen as metaphysical. This hierarchy proclaimed that some organisms by their very essence were superordinal to others – more advanced as ordained by creation. Evidence from Thoreau's writings suggests that he believed that some species of trees (e.g., oaks) were the final species (now referred to as climax) in a stand of forest because they were destined to be so according to the hierarchical framework.

**NOS Tenet: Science vs. Pseudoscience**

- *What distinguishes Thoreau's explanation to account for the Farmers' Problem from the (then) widely-held belief that trees arose spontaneously?*


The belief that new tree species could arise spontaneously aligned with a divine interpretation of life. Here, species were seen as created by God and placed upon the dominion

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**Table 2. Guiding NOS Questions**

NOS Tenet	Guiding Questions
<ul style="list-style-type: none"> <li>Science demands/relies on empirical evidence.</li> </ul>	<ul style="list-style-type: none"> <li>In what ways did past scientist(s) engage in the collection of data?</li> <li>Did they conduct observational analyses? Controlled experiments? Thought experiments?</li> <li>Were any explanations proposed that lacked empirical evidence?</li> </ul>
<ul style="list-style-type: none"> <li>Knowledge production in science shares similar methods.</li> </ul>	<ul style="list-style-type: none"> <li>How did the scientists draw from larger generalizations (laws and/or theories) to inform their empirical work?</li> <li>How did their individual data collection lead toward developing their own generalizations?</li> <li>How did the scientists' explanations provide predictive capability?</li> </ul>
<ul style="list-style-type: none"> <li>Scientific knowledge is tentative, durable, and self-correcting.</li> </ul>	<ul style="list-style-type: none"> <li>Did the scientist's explanation(s) replace or supplant any existing ones? Were there alternative theories to account for the available data?</li> <li>Were any explanations (or methods used to derive them) found to be in error?</li> <li>What caused the replacement of one theory for another? New data? A new perspective on existing data?</li> <li>Did technology play a role in bringing about new data?</li> </ul>
<ul style="list-style-type: none"> <li>Science has a subjective element (theory-laden character).</li> </ul>	<ul style="list-style-type: none"> <li>If there were alternative theories, what differences in backgrounds of the scientists may help us to understand why they proposed different explanations? Did they have access to the same (or similar) data?</li> <li>Were there differences in their educational or philosophical training/grounding?</li> </ul>
<ul style="list-style-type: none"> <li>Science has a creative element.</li> </ul>	<ul style="list-style-type: none"> <li>How did the scientist(s) achieve his/her insights?</li> <li>Did he/she draw from other experiences (non-scientific) or creative endeavors?</li> </ul>
<ul style="list-style-type: none"> <li>There are historical, cultural, and social influences on the practice of science.</li> </ul>	<ul style="list-style-type: none"> <li>How was the scientist's work influenced by the culture in which he/she operated?</li> <li>What ramifications may his/her conclusions have on sociological or political policy?</li> <li>Did any issues of ethics or values come into play with the historical episode?</li> </ul>
<ul style="list-style-type: none"> <li>Science and technology impact each other, but they are not the same.</li> </ul>	<ul style="list-style-type: none"> <li>In what way was technology influential in helping the scientist collect data in support of his/her work? Was technology a necessary component?</li> <li>Did the work of the scientist bring about technological changes or revolutions?</li> </ul>

of the Earth. The succession of an existing tree species by an entirely new species could be explained by this, however, the explanation is not scientific. It is based upon manifest faith in the work of a creator and as such not subject to potential refutation. Thoreau's explanation (a hypothesis or provisional theory) allowed him the capability of making accurate predictions of how succession might proceed in various woodlots depending on the existing species of flora and fauna, and as such, his explanation would be subject to potential tests to refute it.

**NOS Tenet: Scientists Are Partially & Unavoidably Subjective in Their Work (and the Development of Theories) – The Theory-Laden NOS**

- *Might Thoreau's prior philosophical orientation have influenced how he "interpreted" the Farmers' Problem?*

Thoreau embraced the mechanistic philosophy for developing explanations in science. He did not believe in scientific explanations necessarily tied to higher powers or the manifest work of a creator. In fact, Thoreau's writings support that he believed in the transmutation of species. Following a mechanistic perspective, Thoreau believed that natural explanations had causes that were attributable to individual actions that could be identified and isolated.

**NOS Tenet: Scientists Use Creativity To Develop Hypotheses/Theories**

- *What aspects of Thoreau's work on the Farmers' Problem would you regard as "creative"? Why?*
- *Do you think contemporary scientists use similar creative processes?*

Thoreau must have had creative insights to examine and assimilate the observations he made in order to link the distribution of seeds by squirrels (etc.) to the reproductive benefit gained by the trees. It also took creativity to link that squirrels collect and transport seeds as food with the corollary that trees use this process as a beneficial dispersion. Finally, Thoreau was creative in drawing an analogy between crop rotation that farmers normally do with the natural process of seed dispersal and renewal (succession).

**○ Phase III: Designing Instruction To Have Students Explicitly & Reflectively Consider NOS Using the Historical Episode**

The ultimate goal is to design curriculum that has students examine the problems encountered by past scientists in a way that promotes making important connections to the relevant NOS aspects.

## Designing Background Information

That students may lack sufficient background information is certainly an important consideration when designing the lessons. This may inhibit their ability to critically evaluate the context of the problem that will form the basis for their examination at some point during the lesson. Because of this, teachers need to think carefully how to preface the problem with enough historical detail to best prepare students for the lesson. Sufficient background information can take many forms. Sometimes, in order for students to make sense of a problem subsequently given to them, they need sufficient prerequisite conceptual knowledge (i.e., specific biology or physics concepts). In other cases, students will primarily need enough background detail of the interests of a particular scientist, the philosophical leanings of that scientist, and information about any history of ideas, etc. that provides a context for the problem. This is certainly the case with the Thoreau example.

For the Thoreau lessons, I began the first day of instruction by briefly (15 minutes) giving students a summary of Thoreau's interests in natural history, his commitment to the empirical methods derived from the Scientific Revolution, and the influence of his Romantic perspectives on his understanding of nature. During the subsequent lesson, students were invited to read transcripts from Thoreau and his contemporaries, much in the spirit of a case-study approach so that they could interpret the evidence and conclusions made by the actual scientists of the period. The selection of these transcripts came as a result of the initial phase of curriculum development.

## Designing the Problem of Interest

Designing the central problem is of course one of the more critical and time-consuming aspects of the curriculum development, and teachers must use their ingenuity to take aspects of the work they conducted in the first phase of research and modify it for their own pedagogical purposes. Some episodes from the history of science (i.e., the problems that are identified and the evidence that is used to solve them) avail themselves to having students look at data. Sometimes the data can be taken directly from the history of research and modified slightly for ease of use in the classroom (e.g., Howe, 2007). Other times, the teacher will need to think about the conceptual issues raised in the problem (i.e., the explanations and the evidence) and invent a contrived scenario representative of the issues raised in the problem. This was the case with the Thoreau episode. Here, I took the information that emerged from the historical research (encapsulated in Table 1) and invented a problem for students to consider (Appendix A – The Farmers' Problem).

Once students have been given the appropriate background information, the teacher can then provide them with the central problem to consider (Appendix A). The emphasis during instruction is to put students in an active role, whereby in small groups they are encouraged to consider the problem/evidence given to them and come up with one or more explanations to account for the evidence. In the Thoreau case, student groups are encouraged to specify between the evidence they are given, the inferences they make from the evidence, any questions they have, and any proposed explanations they develop. Their ideas are placed on the board for comparative purposes during the whole class session that follows. Group work is then followed with whole class discussions where the various explanations are shared among members and the teacher can have students comment on the merit of each other's answers. Moreover, the teacher can offer additional explanations in those instances where students did not develop one.

## Connecting to NOS

Recall that the second phase of the method for developing curriculum involves identifying relevant NOS tenets using guiding questions that help link the specific work of the scientist(s) to the larger NOS morals (Table 2). The guiding questions used during this process are particularly useful for having students try to connect the work they are doing in examining the scientific problem, their own explanations to account for it, and the explanations proposed by the various scientists themselves. At some point in this process, the teacher can provide student groups NOS probes for them to consider.

As exemplified in the Thoreau lessons following the initial class, students were asked to read through an article written by Thoreau (1906a) in which he presents his specific argument to explain the succession of forest trees (essentially his account of the Farmers' Problem). Students were also provided an excerpt from another article where Thoreau makes additional observations related to tree succession (Thoreau, 1906b) and they were given excerpts from other naturalists who proposed alternative explanations. Students were challenged to identify the various explanations (and evidence for/against) that Thoreau himself discusses. At the same time, students were given NOS probing questions to consider while they were reading the historical pieces. These NOS probes were taken directly from the second phase of NOS research that I had done where I had identified any germane NOS tenets. The idea was to have students consider the NOS questions in concert with the problem they had attempted to solve during class and with the readings that captured Thoreau's argument to the problem.

In the subsequent class (Day 2), students were invited to share Thoreau's perspective, and this information was placed on the board next to what the students had proposed from the previous class. During a whole-class discussion, students were challenged to critically evaluate the various explanations, and they were invited to reflect upon the NOS questions given to them. In this way, NOS was a planned instructional event (explicit), and because students were put in the position of their having to consider the NOS probing questions in concert with the work they did to interpret the problem, they were challenged to reflectively link NOS to a specific (i.e., scientifically meaningful) context.

## ○ Summary: Advantages of This Method

The preceding method describes how to integrate explicit/reflective NOS instruction using problem-based lesson(s) developed from episodes in the history of science. The advantages of this approach draw support from several areas within science education and cognitive science research.

First, the method assumes as its basis that science is essentially a problem-solving endeavor. Therefore, to the extent possible, lessons that hope to expose students to learning "about science" should be done in a manner consistent with how scientists operate. It is for this reason that the method stresses to teachers that they use certain guiding questions to flush out the significant problems of interest, the evidence that the scientists used to develop explanations to account for the problems, and the disparities (if applicable) in explanations that were proposed. Correspondingly, placing a curricular emphasis on explanations and evidence aligns with what science educators point out as fundamental processes in science (Duschl, 1990), and it avails itself to having students develop critical reasoning in argumentation (Monk & Osborne, 1997).

Second, the method links NOS instruction to what is a context-rich learning experience with the history of science. The advan-

tage of this as discussed by Clough (2006b) is that when students learn NOS within a contextual framework, they are less likely to exit instruction with dualistic thinking of NOS tenets. Put another way, when NOS instruction is not linked to context (e.g., when NOS is taught only using “black box” activities), students are more inclined to consider NOS as something that only applies in terms of the decontextual activity and not with respect to the practice of real science.

Finally, the method draws from research (Howe & Rudge, 2005; Khishfe & Abd-El-Khalick, 2002) that demonstrates the importance and efficacy of promoting students to both explicitly and reflectively learn fundamental NOS tenets. Here, the central argument is that NOS tenets should be viewed as cognitive constructs and as such are things that students must meaningfully learn on their own, with the instructor helping to scaffold their concept learning. Thus, instruction must provide opportunities for students to build upon their existing conceptions of science. In this method, the reflective element of NOS probes and subsequent small group and whole-class discussions emphasizes *qua* the constructivist philosophy the cognitive learning of NOS.

My introductory biology course is designed primarily for preservice elementary and secondary education students. Over successive units, students are repeatedly challenged via open-ended problems and classroom discussions to develop their own conceptual understanding of fundamental biological concepts. My role as an instructor is to introduce the problems that students examine, help model problem-solving strategies, and initiate/direct discussion about aspects that concern either the conceptual topics or more generally when some part of students’ work raises important connections to NOS.

I have implemented the Thoreau lessons in my ecology unit over three successive semesters, and I have been impressed with how students have approached the readings and the manner in which they discussed connections to NOS. Furthermore, in my ecology unit exam, I presented students with decontextual questions about NOS and invited them to reflect about their under-

standing. A substantial number of students not only gave fairly informed conceptions of NOS but, perhaps more noteworthy, they supported their answers with specific aspects of the Thoreau case. Admittedly, I am cautious not to overly extrapolate the effect of one brief intervention on students’ tenacious views of NOS, but still my anecdotal experience/evidence is encouraging, and the method does align with theoretical approaches for how we should teach contextualized NOS concepts. Readers interested in a more empirical analysis of the effect of a similar method of instruction using a case-study approach to understanding sickle-cell anemia are encouraged to take a look at the article in *The American Biology Teacher* (Howe, 2007) or otherwise (Howe & Rudge, 2005).

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## Appendix A. The Farmers' Problem

To the right is a hypothetical diagram of a farmer's field that is surrounded on three sides by different forest stands. Below the diagram are illustrations of the species of trees (and their seeds/cones where applicable) and the annual goldenrod.

Assume that each of the forests (A, B & C) are at least 40 years old. It is also safe to assume that there are no other mature species of trees in each of the forests other than those given under the forest headings. Each forest does contain occasional seedling trees (approximately 6 to 18 inches tall) of various species, and each of the forests contains stumps from the cuttings of many years past.

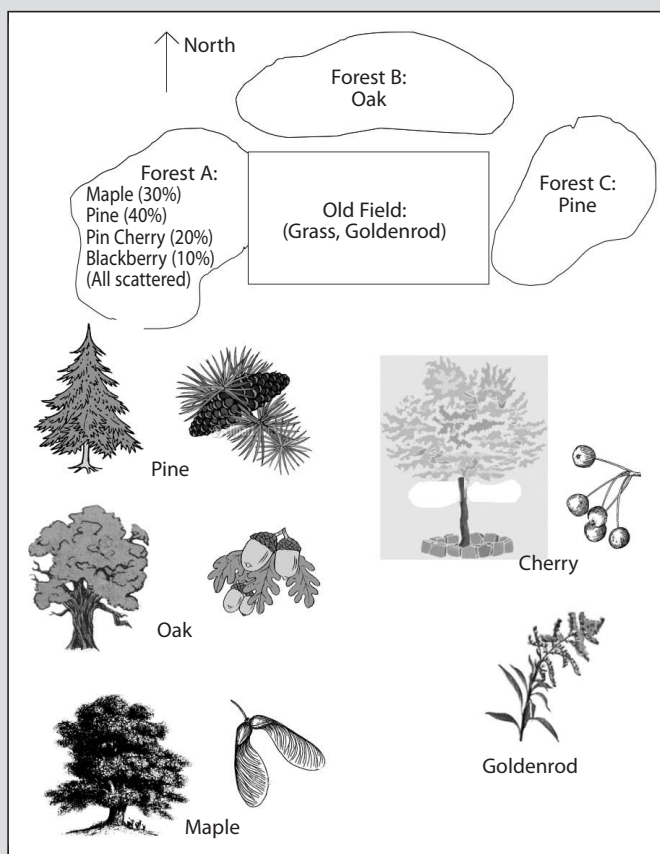
The farmer decides to harvest his pine field (Field C). This is accomplished by literally sawing the mature trees (largely the entire forest) by cutting them at the base, thereby leaving stumps behind from which new sprouts may possibly grow (a practice that was commonly done to start tree growth).

Many years pass, and the farmer (or perhaps his/her children) notice that what was once a pine forest in Field C has now become principally an oak forest.

Farmers with other similar plots also notice that in those instances where oak fields were harvested for lumber (like the original Field B), they were eventually replaced by pine trees.

Using the information below in the table and the diagram and illustrations to the right, I want you to come up with various explanations to account for the farmers' observations. (Where did the oak trees that took over the harvested field [C] come from?). You may decide that much of the information in this table is not useful for now. You may also decide that you need more information for one or more of your explanations. That is fine - make note of any questions that you may have. Consider as many explanations as you can, even those that may seem unusual.

Also: How might someone from the 19th century, who believes in the divine creation of life, explain what is occurring in the fields?



Species	Avg. Height	Growth Rate	Avg. Age When Capable of Reproducing	Seed Dispersal	Optimal Seedling Light Conditions	Adult Shade Tolerance	Life Expectancy (Years)
Oak	80'	Slow	10 years	Acorns (Heavy) - Drop & Critter	Low Light	Moderate	80 - 100
Pine	60'	Slow	10 years	Cones (Seeds) Wind	Mod. Light	Moderate	50 - 60