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Grant Report

"Culturally Relevant Science: An approach to Math Science
Education for Hispanics"

Grant # DE-FG03-96ER76047

Organization- SACNAS

P.I. Bernard Ortiz de Montellano

November 14, 1996

As planned a letter was sent out to 17 teachers who had participated in a Summer 1994 workshop on "Culturally Relevant Science for Hispanics" at Michigan State. These teachers were supposed to have spent the intervening time developing lesson plans and curricula. The letter requested a report of any activities undertaken and copies of lesson plans and materials developed by February 1996 with a stipend of \$400 for satisfactory reports. We were disappointed to only get 9 responses and not all of them demonstrating a satisfactory level of activity (people who did not submit completely satisfactory reports were only paid \$200). Diana Martinez, Dean of Science at Texas A&M University, Corpus Christi, who is the other developer of this curriculum and I reviewed the submitted materials and chose those showing the most promise to be invited to participate in the Summer Writing Workshop.

Spring of 1996 and particularly in May-June, Bernard Ortiz de Montellano wrote a partial first draft of a companion volume for the teacher's manual which would provide a rationale for doing culturally relevant science, present the cultural and the scientific background that teachers would need in order to be able to teach. One of the goals of this curriculum is that it should be off-the-shelf ready to teach and that teachers would not have to do extra research to encourage its adoption. The outline of the book is Appendix 1 (Bolded entries have been written). Several papers by Ortiz de Montellano include topics in I and will be added later. Xerox copies of these chapters together with teaching tips and bibliography were sent to all the participants of the Workshop before it began except for the chapter on mathematics which was distributed at the meeting itself. Appendix 2 is a sample chapter from the book.

June 4, 6 teachers were invited to participate in the Writing Workshop: JoAnn Montes McDonald (Ph. D. Candidate, Science Education, University of Texas, Austin), Helen Mebane (Memorial Middle School, Kingsville, Texas), Mercedes Merrell (Acacia Elementary School, Fullerton, California), Tina Muñoz-López (Papago School, Phoenix, Arizona), Martha Smith (Bachrodt Academy, San Jose, California), and Berta Ugalde (California

Museum of Science and Industry, Los Angeles). Unfortunately, Mercedes Merrell could only participate for the last week, and JoAnn McDonald was only available for 4 days.

The Writing Workshop was held at Texas A&M University, Corpus Christi from July 14 to July 27, 1996. Minerva Mares-Lares, a bilingual teacher from Kingsville who works with Mebane, attended voluntarily with no stipend. Ortiz de Montellano and Martinez held an orientation session outlining the goals of constructivist education and the philosophy of culturally relevant education, as well as debriefing participants about the material sent in advance. Participating teachers chose topics that they were interested in developing and wrote first drafts, these were distributed to all participants and critiqued by the workshop directors before being rewritten. Some teachers were more productive than others depending on their science background. In total an impressive number of lesson plans were written. These lesson plans are listed in Appendix 3, Appendix 4 is a sample lesson.

Work still needs to be done on both the source book and the teacher's manual. Part I of the book needs to be added as well as the two missing chapters, additional drafts of the text need to be done, and appropriate illustrations need to be chosen. The teacher's manual needs an introduction on the philosophy of teaching culturally relevant science and on the constructivist teaching approach that we espouse. A long illustrative example on how to constructively teach photosynthesis developed by Diana Martinez while team teaching a 5th grade class in Okemos, Michigan is partially written and needs to be completed. The class exercises need to be rewritten into a common format and correlated with the appropriate goals from Project 2021's Benchmarks for All Americans and the National Academy of Science's Science Standards. Ortiz de Montellano is scheduled for a sabbatical Winter Semester of 1997 and will devote full-time to finishing the remaining tasks. At that time, the curriculum will be ready to be introduced to teachers in workshops conducted by the Principal Investigators, members of the writing team, and additional master teachers who will be trained in this curriculum. Feedback and experience from these workshops will be used to rewrite both the source book and the teacher's manual, and additional examples, particularly in the physical science will be developed. At some time in the future, commercial publication and wider dissemination will be targeted.

Further efforts are ongoing to disseminate and improve the material. JoAnn McDonald has developed both a lesson plan on nutrition and a 2 1/2 hour workshop on this topic that can be used to introduce the culturally relevant approach to this topic

in a constructivist manner. She did this workshop at the 1996 Annual SACNAS Meeting, in Los Angeles, October 23-24, and will continue to improve it. This workshop will become the standard introduction to this curriculum and will be learned by all our presenters.

Berta Ugalde has been very active in developing and disseminating this approach. She taught a series of classes on culturally relevant science in continuing education for teachers at the University of San Diego. She ran a workshop at the California Museum of Science and Industry to pilot test the exercise on Aztec wound treatment and the participants came up with a number of improvements. Berta together with Martha Smith cooperated with Diana Martinez in presenting a workshop on archaeoastronomy at the annual SACNAS meeting in order to learn how to present the topic. Finally, Berta is organizing an all day session at the 1997 meeting of the Greater Los Angeles Teachers Science Association (GLATSA) February 22. Berta will present a workshop on Mesoamerican pigments, Helen Mebane will present her workshop on Mesoamerican dyes and agave fibers, a new participant, Thelma Hernández, will do a workshop on raised-field agriculture (chinampas). The day will end with a panel discussion on culturally relevant science in which Berta, Thelma and Helen will participate as well as Martha Smith and Maria Elena Zavala, Professor of Biology at California State University-Northridge, who is a long-term supporter of culturally relevant science.

Martha Smith has been working on improving and refining the geology components of the Teacher's Manual, assisted at the SACNAS meeting, and will participate in the panel discussion at GLATSA. Helen Mebane has been working extensively on developing a workshop on the chemistry and use of cochineal. The workshop was presented at the SACNAS meeting and will be repeated at GLATSA. Tina López will be using the culturally relevant approach for her presentation in a graduate class demonstration for master teachers and is working on either Ortiz de Montellano or Martinez coming to lecture teachers in Phoenix. Diana Martinez is working with a group of teachers in Corpus Christi exploring how to integrate culturally relevant examples into the Texas mandated curriculum.

Summarizing, the most difficult part of the project, developing the concepts and writing down the first draft of most of the material is done. What remains is to polish the writing, finish the missing material, and prepare a package that can be field tested in teacher workshops. Simultaneously, all of us are engaged in publicizing the concept in a variety of venues (Ortiz de Montellano has been asked to write an article on the topic for Technology Review). Cultural Relevant Science has received an

impetus that assures the completion of the instructional package.

Appendix 1

Outline of book on Culturally Relevant Science February 29, 1996

I. Introduction

A. Need for the thing.

1. Shortage of minorities in science.
2. Science for all arguments

B. Rationale for "culturally relevant"

1. People role models not enough. We need to actually teach some science not just work on role modeling.
2. Failure of established science to address. Still "dead white males."
3. Should replace topics already covered not add to teacher's burden. Should look at topics recommended in Benchmarks
4. Absolute accuracy is necessary, both in science, in anthropology, in historical data.
5. Should use examples that are grade appropriate.
6. Allows teacher to teach "across the curriculum"
7. Should use the best available pedagogy-- i.e. less is more, constructivist approach. hands-on, discover approach.
8. Not "centric" anything. Although here doing Mesoamerican examples, goal should be that over course of year all ethnic groups shown as participants.
9. goals of Culturally relevant science.
10. should provide sufficient detail, references, exercises so that teachers can present "of-the-shelf"
11. teach science as practice separated from motivation of religion (also motivated West till after Newton)
12. Question of self-esteem
 - a. important but the key is not to lower standards but to demand a lot, be supportive, praise but be realistic. Stevenson work, Gandara paper, Pygmalion effect. Cruel in long run to praise low quality work and not provide standards (cite Calif. Framework), "success?" program pushed by NYC chancellor.
 - b. examples of programs that work: Marva Collins, Baltimore Barclay school, Gibbons article science

C. Failures due to vacuum and hunger for multicultural science

1. Afrocentric science (Portland, Van Sertima, Asante), widely dispersed.
2. shoddy sources.
3. pedagogic problems ("mentioning problem", prof by assertion, inappropriate topics) do not use modern approaches
4. post-modern perspectivist claims as background for glorifying Egyptian/African accomplishments (also now being used by Native Americans)
5. Claims that religion is paradigm for science (blurs magic, violates Constitution)
6. claims that paranormal exists and is scientific
7. failure to withstand critical thinking (examples)
8. self-esteem, feel-good, rather than learn science-- counterproductive--Joe Graves morphine for a cancer
9. Other cultures following suit-- Native Americans, Vine Deloria Red Earth, White Lies (unfortunately pushed by AISES), Banks,

Christine etc.

D. Pitfalls in multicultural

1. Cut and paste 9 from Detroit criteria with two headings Accuracy and Content. State these are the most meaningful. We have problems with some of the other criteria as redundant or not unique to multicultural (i.e. no books should have propaganda)

2. Pitfalls

- a) documentation; 1. There is an order of credibility of sources.
2. Check for complete citations. 3. Watch out for lots of typographical or spelling errors. Careless in details means careless on facts.
- b) Authors\credentials
- c) Sufficient Depth
- b) Watch out for the use of scientific sounding terminology or the inappropriate use of scientific terms. cite examples of "newspeak", Adams, Argüelles, etc
- c) Political agendas can distort even simple facts, Nile, melanin
- d) Out of Context Content
- e) Overfocus on a group
- f) Need to avoid pseudoscience and the introduction of religion/supernatural/magic/New Age beliefs masquerading as science

E. Describe science

- 1) use outline of Feder's chapter on how do we know
- 2) get into EVIDENCE, EVIDENCE
- 3) guess and test
- 4) discuss and rebut the post-modernist stuff; deal with the inapplicability of the Heisenberg Uncertainty
- 5) Discuss- Malinowski and science; how the Maya astronomy fits

II. Historical-Cultural background

A. Describe limitations of what we will cover. Basic outlines, pick areas that we will need for support of the science activities we will describe. Not possible to do a complete survey but will put books in bibliography. Will include some primary sources just so that teachers will know about them.

B. Sources and how do we know about Mesoamerica. (primary sources, archaeology, conqueror documents, ethnographies

C. Migration and early development

D. Olmec

E. Teotihuacan

F. Maya

G. Aztec

H. Religion, gods, supernatural, magic

I. Calendars

J. mathematical backgrounds, Maya, Aztec (with codices)

K. Astronomy

L. Foods and nutrition

M. linguistics, word roots etc

N. plants, agriculture, bugs etc

III. Specific exercises

A. Archaeoastronomy

B. Maya mathematics

C. Maya Astronomy

Appendix 2
November 19, 1996 miscellaneous chapter

Pronunciation note (from Leon Portilla 1969, p. xiii)

In general, it can be stated that all the vowels and most of the consonants have phonetic values very similar to those they have in Spanish. There are, however, some important exceptions.

- 1) *h* is pronounced with a soft aspiration as in English.
- 2) *tl*, frequent in Nahuatl, the language of the Aztecs, and *ts* and *tz* represent single sounds and should not be divided.
- 3) *u* before *a, e, o, i* is pronounced like the English *w*.
- 4) *x* as in sixteenth-century Spanish, has the same sound as the English *sh*
- 5) The Maya languages are rich in glottalized consonants to be pronounced with a constricted throat.
- 6) Practically all Nahuatl words are accented on the next to last syllable. Many Maya words, on the other hand, have the stress on the last syllable.

Word Origins

Plants and animals

	source	word	Puerto Rico	English
achiote	Nahuatl	achiotl		annatto
aguacate	"	auacatl		avocado
arroz	Arabic			rice
atole	Nahuatl	atolli		
cacahuate	"	tlalcacahuatl	maní	peanut
cacao	"	cacahuatl		cocoa
camote	"	camotli	boniato	sweet potato
cenzontle	"	centzontli		mocking bird
chocolate	"	xocotlatl		chocolate
chapulin	"	chapolin		grasshopper
chayote	"	chayotl		
chicle	"	tzictli		chewing gum
chile	"	chilli		chili
coyote	"	coyotl		coyote
ejote	"	exotl	habichuelas tiernas	green bean
elote	"	elotl		young corn
escuintle	"	itzcuintli		dog
guacamole	"	auacamolli		guacamole
guajolote	"	uexolotl		turkey
hule	"	olli		rubber
jitomate	"	xictli tomatl		tomatillo
maguay	taíno			agave
maiz	"			corn
mezquite	Nahuatl	mizquitl		mesquite
mole	"	molli		
nopal	"	nopalli		cactus
pavo	Latin			turkey
peyote	Nahuatl	peyotl		peyote
pinole	"	pinolli		powdered corn
platano	Greek		guineo	banana
platano macho			platano	plantain

pozole	Nahuatl	pozolli	
quelite	"	quelitl	
tabaco	taino		edible green
tamal	Nahuatl	tamalli	tobacco
tecolote	"	tecolotl	tamle
tejocote	"		barn owl
tlacuache	"	tlacuatzin	
tomate	"	tomatl	opossum
tortilla	Latin		tomato
verdolaga	"		tortilla
yuca	taino		
zacate	Nahuatl	zacatl	yuca
zapote	"	tzapotl	grama
zopilote	"	tzopilotl	cassava
			grass
			vulture

Other terms

achichinle	Nahuatl	achichinqui		servant
chapopote	"	chapopotl		tar
chiche	"	chichi		breast
comal	"	comalli		griddle
cuate	"	coatl		pal, twin
gachupin	"	cactlitzopini		Spaniard
				(derogatory)
jacal	"	xacalli		hut
machete	"	maxelotl		machete
mano	Latin		maceta	pestle
mayate	Nahuatl	mayatl		beetle
metate	"	metatl		grinding
stone				
mitote	"	mitotl		party
molcajete	"	molcaxitl	pilón	mortar
nagua	taino	falda		skirt
olote	Nahuatl	olotl		corn cob
pepenar	"	pepena		to pick up
petaca	"	petlacalli	baúl	suitcase
petate	"	petatl		reed mat
popote	"	popotl		straw
tocolote	"	texolotl	maceta	pestle
zoquete	"	zoquitl	lodo	mud

Sources:

Francisco Santamaria, Diccionario de Mejicanismos, Mexico: Porrúa, 1978.

Diccionario de la Real Academia de la Lengua *****

For a humorous interlude. Admonitions from the elders to children on how to behave. This can be adapted into more modern language to attract children. (example in bold) from Sahagún, Fr. B. de. 1950-1982. Florentine Codex, C. E. Dibble and A. J. O. Anderson, eds. and trans. Salt Lake City: Univ. of Utah Press. Book 6, ch. 22,

P. 121-122 [rules of the road] "And second: thou art to be prudent in thy travels; peacefully, tranquilly, deliberately art thou to go, to take the

road, to travel. Do not throw thy feet much [don't burn rubber], nor raise thy feet high, not go jumping, lest it be said of thee, lest thou be named fool, shameless. Neither art thou to travel very slowly, nor to drag thy feet, lest it be said of thee that thou art a dragger [no drag racing], thou art a lout, thou art a fat one; lest it be said of thee that thou goest waddling, that thou goest like a mouse [don't go under the speed limit] also lest thou turn thyself into an object of derision, incline thy head, travel like a pregnant woman. Nor art thou to go trampling; thou art not to seem like a firefly [don't weave all over the road], not to strut, not to bustle about [don't hog the road], lest it be said of thee that thou art only an old thing, that thou art shameless.

.....

P. 123 [dress code] "Seventh: as thou art to array thyself, as thou art to clothe thyself, thou art not to dress vainly, thou art not to array thyself fantastically, thou art not to place on thyself the gaudy cape the gaudy clothing, that which is embroidered don't wear flashy or provocative clothes]. Neither art thou to put on rags, tatters, an old loosely-woven cape [don't wear old baggy jeans with holes]. ... Thus art thou to tie on they cape: do not tie it on so that thou goest tripping over it; neither art thou to shorten thy cape. Moderately are thou to tie it on. Nor art thou to expose thy shoulder [don't ear cut-offs]. The quachic, the so-called furious in war, he who goeth confidently encountering his death, and the entertainer, and perhaps the buffoon, or perhaps the dancer and the mad, all snatch the cape of whatever kind; they drag it; they trip over it; they go about mocking, they go rudely, they go drawing it to the arm pit, shoulder bared; they go in conceit, graceless, dragging their feet, twisting and turning as they travel. And their sandals are wide and long, the straps dragging, and their excessively long sandal thongs [also] dragging [don't imitate the jocks who wear their Nikes with the laces untied]. But, as for thee, be thou always prudent as to the cape the sandals; place on thee that which is always good, proper, all fine.

p. 124 [table manners] "Eight: Listen! Above all thou art to be prudent in drink, in food, for many things pertain to it. Thou art not to eat excessively of the required food [don't eat like a pig]. And when thou dost something, when thou perspirest, when thou workest, it is necessary that thou art to break thy fast. Furthermore, the courtesy, the prudence [thou shouldst show] are in this wise: when thou art to eat, thou are not to be hasty, not to be impetuous; thou art no to take excessively nor to break up thy tortillas [don't play with your food]. Thou art not to put a large amount in thy mouth [don't stuff your mouth]; thou art not to gulp like a dog, when thou art to eat food.

Thou art no to let thyself choke on the food, not to strangle. Thou art to drink, to eat slowly, calmly, quietly [eat slowly, chew your food don't gulp it like a dog]. Thou art not to stir up the pieces, not to dig into the saucebowl [don't pick around in the serving bowl], the basket. Take care lest the choking on food, the strangling should befall thee here. How hath it come about that thou hadst caused laughter at the place of eating? Quickly hadst thou fallen to the ground if thou hadst choked. And they would mock thee for it; a great quantity of that which is savory they would arrange for thee, for thou wouldst yet nourish thyself. But because thou wert a glutton, thou wouldst fall on the ground when thou wert to eat. Rather, thou wouldst be intemperate. Therefore also art thou a spectacle [don't make a spectacle of yourself by the amount and the way you eat your food].

And when already thou art ready to eat, thou art to wash thy hands, wash thy face, to wash thy mouth [wash your hands before you eat]. And if somewhere thou art to eat with others, do not quickly seat thyself at the eating place with others. Quickly thou wilt seize the wash water, the washbowl; thou wilt wash another's hands. And when the eating is over, thou art quickly to seize the washbowl, the wash water; thou art to wash another's mouth, another's hands. And thou art to pick up [fallen scraps], thou art to sweep the place where there has been eating [don't rush off without helping to clean up]. And thou, when thou hast eaten, once again art thou to wash thy hands, to wash thy mouth, to cleanse thy teeth [wash your hands and brush your teeth after eating]."

Aztec Riddles (zazanilli)
Sahagún (1950-1982: Book 6, 237-240)

1. What is it that is a small blue gourd bowl filled with popcorn?
One can see from our little riddle that it is the heavens.
2. What is that which is black, writing with liquid lead?
The crawling snail.
3. What is that which is a small mirror in a house made of fir branches?
Our eye.
4. What is that which grinds with flint knives, in which a piece of leather lies?
Our mouth.
5. What is that which has a small wrinkled face, then goes kicking?
Our knee.
6. What is a small white stone holding a quetzal feather?
The onion.
7. What is that which we enter in three places [and] leave by only one?
It is our shirt.
8. What is that which becomes pregnant in only one day?
The spindle.
9. What is that which stands at the edge of the hearth, rising with a curve at the end?
The dog's tail.
10. What is that which follows along the gorge, going clapping its hands?
The butterfly.
11. What is the black stone standing on its head, resting listening to the land of the dead?
It is the beetle.
12. What is that which is a stone of red ocher which goes jumping?
The flea.
13. What is that which is rounded above, which shakes, which cries out?
The gourd rattle.

14. What is that which is filled with shields within?
It is the chili; and its seeds are shields.

Pigments and dyes¹

There is a wealth of material that could be included under this topic. It is also an area that is particularly suitable for discussion of many cultures because every group has beautified their environment with color. There are interesting scientific aspects as well because similar chemical structures have been used as dyes by widely separated cultures. The physics of color and the chemistry of dyeing are also interesting but beyond the scope of this text.

Pigments are finely divided insoluble materials used to color other materials. Pigments do not react with the substance on which they are painted nor with air or water. The most stable pigments are metal oxides because they are so unreactive, but they can also derive from animal or vegetable sources although the latter fade much sooner. Pigments are applied in a "vehicle" to carry the pigment and provide the proper consistency as well as with a "binder" to make the pigment stick to the surface. Dyes react with the substrate and are most often organic in origin.

The earliest chemical used as a pigment was probably blue frit found in the tomb of Perneah (2650 B.C.) in Egypt. Blue frit is copper silicate (Friedstein 1981). Other ancient Egyptian pigments included arsenic sulfides (As_2S_3 , realgar--red; As_2S_5 , stibnite--yellow), copper carbonate ($\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$, malachite--deep blue), iron oxide, hematite (Fe_2O_3 --red), and carbon (lampblack). These pigments were suspended in hot wax as a vehicle and left to dry (Friedstein 1981). Many of these same pigments were used in Mesoamerica as well as in other parts of the world.

Hematite was the source of the red color favored by the Olmecs, and used in San Lorenzo. Thus it is the oldest pigment in Mesoamerica. The most common color associated with Maya plastered surfaces and carved monuments was a dark red iron oxide. Ground up hematite could be mixed up with water or with animal fats as a vehicle so that it could be applied to the surface. The Maya probably used the resin, copal, as a vehicle because their pigments adhere like varnish to surfaces (Sharer 1994: 642-643). Iron oxides provided a variety of shades from yellowish to brown, varying proportions could be mixed to produce a particular shade. Mercury sulfide (HgS , cinnabar) was highly prized by the Maya apparently because the color symbolized blood, and was included along with hematite in offerings (Pendergast 1982).

Copper compounds like the copper carbonates, malachite and azurite provided pigments in different shades of green to blue-green. White pigment was primarily limestone, calcium carbonate, CaCO_3 , which provided a "chalky" whitewash. Burning limestone produced the lime (CaO) that was essential for the construction of buildings. Heating dry bones in plenty of air produced bone white (calcium phosphate, $\text{Ca}_3(\text{PO}_4)_2$), while burning bones or organic

1. The Florentine Codex describes a number of pigments and dyes (Sahagún 1950-1982: book 11, 239-245).

material with a very limited amount of air produced lampblack, or bone black a charcoal that was ground to produce a black pigment. Yellow shades were obtained by using ocher (a clay mineral containing iron oxides). Red and yellow ochers as well as black pigments were used in the wall paintings of the Olmec cave at Juxtlahuaca.

One mysterious pigment is "Maya blue" a lovely vivid blue that was the second most common color in Maya paintings. It is not one of the usual sources of blue such as copper minerals. It now appears that "Maya blue" is a clay, attapulgite, commonly found in the Maya area, that has been impregnated with the plant dye, indigo (discussed below) and heated. Apparently, heating the clay-dye mixture produces a color that is very stable differing from most organic pigments (Littmann 1982).

Pigments used in Mesoamerica

<u>mineral</u>	<u>compound</u>	<u>color</u>	<u>Aztec name</u>
hematite	iron oxide	red-orange	tlahuitz
hematite. (H ₂ O)x	hydrated iron oxide	yellow to orange	
malachite	copper carbonate	green	
azurite	copper carbonate	blue	
ocher	clay + iron oxide	red-yellow	tlahuitl
cinnabar	mercury sulfide	red	
chalk	calcium carbonate	white	tizatl
limestone	calcium carbonate	white	tetizatl
bone white	calcium phosphate	white	
lampblack, charcoal	carbon	black	tlilli
Maya Blue	attapulgite + indigo	blue	

Dyes

Many dyes in plants are glycosides, that is, they are bound to a sugar to increase the water solubility. During the dyeing process these bonds are broken and new bonds are formed between the dye and the fiber being dyed producing a water insoluble color. Broadly speaking dyes can be classified into three types: 1) direct dyes-- dyes that bond directly to fibers with no intermediaries (examples bixin, lawsone); 2) mordanted dyes. Fibers are pretreated with a solution of a metal salt (aluminum, iron, copper, tin, or chromium) and the metal ion binds to both the fiber and the dye. Most natural dyes can be applied with mordants, and different metal salts will produce different colors with the same dye; vat dyes are dyes that must first be reduced to a water soluble form, the textile is treated in the water solution and the dye is oxidized on the fiber to produce the final color (Tyrian purple, indigo).

Considering that there are hundreds of thousands of plant species and correspondingly millions of possible chemical structures it is very interesting that different cultures end up using either the same or similar plant species as dyes and that important dyes have fairly similar chemical structures (see table of dyes and chemical structures at the end of the chapter). The limited range of really good dyes and the difficulties associated with their preparation meant that after William Perkin's discovery of, mauve, the first synthetic dye, in 1856 synthetic dyes have replaced natural dyes for most uses.

Good blue dyes were somewhat limited in antiquity. In fact, most dye plants contained the same chemical, indigo. Woad (Isatis tinctoria) was known both in Egypt and Mesopotamia and was the principal blue dye of Europe. It is widely distributed in Europe, Asia, and North Africa. It is famous as the dye with which the Britons smeared their bodies to paint themselves blue much to the amazement of the conquering Romans (Pliny 1948-1960: 22.2.2). Indigo which comes from the plant Indigofera tinctoria was known in India about 2500 B.C. and in Egypt it was found on a cloth dating to the 5th Dynasty (ca. 2500 B.C.) but did not become common until 300 or 400 B.C. Indigo contains ten times the concentration indigo as woad and therefore was preferred when ever there was a choice. In the New World, the indigo containing plant was Indigofera suffruticosa, añil,² or tlacehuilli in Nahuatl. In Japan the traditional blue dye was obtained from the plant tade-ai (Polygonum tinctorium), but the dye was our familiar, indigo (Torimoto 1987). Indigo and Tyrian purple (discussed below) are "vat dyes" that can produce color-fast dyes all by themselves although their need for reduction by fermentation followed by oxidation to produce the final dye makes the process long and complicated. In the plants, the dye exists as a colorless compound, indican. When the leaves are crushed, the indican is slowly converted into a water-soluble colorless compound, indoxyl. Thus, preparing woad or indigo involved a more-or-less lengthy period of fermentation to liberate the indoxyl. The solution was then made alkaline by putting in urine,³ the cloth to be dyed was dipped in the colorless solution and then hung to dry in the sun. The exposure of indoxyl to oxygen oxidized it and formed the blue insoluble indigo on the cloth.

indican

indoxyl

indigo

The most prized color in antiquity, in the Old World, was Tyrian purple. It was obtained from species of mussels (Murex trunculus, M. brandaris, and Purpura haematoma in the Old World, Purpura patula in the New World). The dye is indigo with two bromine atoms added. Its use goes back far into pre-classical history, although it reached its peak when production was controlled by the Phoenicians, who kept their methods a secret. This industry existed in Phoenicia as early as 1439 B.C. The imperial dyeworks of Tyre were destroyed by the Arabs in A.D. 638. The full dyeing process was probably first developed by the Minoans of Crete, but in 1500 B.C in Ugarit, Syria, a tablet refers to

2. Spanish from the Arabic an-anil "the indigo."

3. The urea in urine decomposes to ammonia, which makes the solution alkaline.

the process. Pliny (1948-1960: IX, 125-142) describes the dyeing process as follows. The mussels were crushed and steeped in water with added salt for nine days (in order to produce the dibromoindoxyl) and the solution was then strained. The clean material to be dyed was then soaked for five hours in the solution. The yellow-colored cloth was exposed to sunlight and air so that the full dye color would develop. The juice from Murex brandaris changed into a deep violet, while the juice from M. trunculus and Patula haemostoma gave a scarlet-red color. The evidence for the antiquity of the production of Tyrian purple in the New World is less compelling. We do not have written evidence in Aztec or Maya sources for its use. However, we have spectroscopic evidence of cloth dyed with this dye that is over a hundred years old, and Guatemalans use the dye today (Carlsen and Wenger 1991). The problem is complicated because the well-known cochineal can produce purple hues with the proper mordant, and thus not all ancient purple is evidence of the use of mollusk dye. The dye process in the New World differed from the one described by Pliny because the New World mollusk does not have to be crushed to obtain the dye-containing juice. Barber (1991: 228) points out that in Central America the natives irritated the mollusk by rubbing it onto the yarn to be dyed and thus transferred the colorless juice onto the yarn and the subsequent exposure to sunlight and air formed the dye.

Yellow dyes seem to be associated with food, and they require a mordant in order to get satisfactory fastness. Safflower (Carthamus tinctoria) which produces an impermanent yellow dye as well as a red dye, carthamic acid was used in Egypt by 2000 B.C. There are Minoan frescoes depicting the gathering of saffron (Crocus sativus) in the 2nd millennium B.C., and it grew and was used in Syria and Egypt. The rind of unripe pomegranates (Punica granatum) were ground and extracted with water to give a dye as early as 2000 B.C. in Mesopotamia, and it was used in Egypt from 1500 B.C. onwards. Turmeric (Curcuma longa) was used as a yellow dye as far back as Assyrian time. One of the best yellow dyes, weld (Reseda luteola) a native of South-eastern Europe, was not used until a thousand years later, and was probably introduced to the West by the Romans. Achiote, which is a key ingredient in Mexican and Puerto Rican cooking, is the pre-eminent yellow-orange dye of pre-Columbian Mesoamerica. Saffron, the key ingredient of Spanish paella, was much used as a dye in antiquity. In antiquity it grew in Syria and Egypt. The Phoenicians gave saffron-dyed textiles to the Assyrian king Assurbanipal as tribute. The chemical structures of both of these dyes are very similar, and differ from those of the other yellow dyes discussed.

Genista tinctoria, dyer's broom or greenweed, was the heraldic flower of the English Plantagenet kings. The ends of the branches were boiled to extract the dye, and alum (aluminum oxide) was used as a mordant to dye wool. The yellow wool was then immersed in a second vat containing woad to produce a green color (Forbes 1964: 124). The dye, rhamnetin, was extracted from the dried, unripe berries of Rhamnus infectorius with hot water and used with an alum mordant followed by sodium carbonate to give a yellow color. Using a tin mordant produces an orange color, and a reddish color can be produced by using frozen rather than dried berries. Egyptians, in the late Papyrus Holmiensis, describe a substitute for the authentic but expensive purple by pretreating wool with henbane and lupin before dyeing with Rhamnus (Forbes 1964: 125).

Red was one of the most popular colors and was found among the earliest dyed fibers in Mesopotamia, Egypt, the Levant, and the New World. One of the reasons for this preeminence is physiological because we distinguish visible

light most easily and accurately at the "red" end of the spectrum.⁴ Red is often synonymous with "beautiful" in many cultures-- for example the Russian Red Square really meant "Beautiful Square" when it was built. The Aztecs used the difrasismo (two word metaphor) in tlilli, in tlapalli ("the black and the red" the colors used in writing the codices) as a metaphor for wisdom.

The dye, henna is used more often as a colorant for skin and hair than for cloth, and its use in Egypt dates to at least 2500 B.C. The hands and feet of female mummies are often painted with henna, and the hair of Nefertiti's grandmother, Tuya, and of Ramesses the Great was dyed with it. Today, henna is used all over the Middle East. Elaborate designs requiring several hours to apply are painted on the hands and feet of women celebrating their engagement or their wedding. Henna is used more routinely to color fingernails or to dye hair.⁵ Madder, which usually requires an alum mordant, has been identified on cloth from Tutankhamen's tomb (1323 B.C.), and even on a cotton cloth from Mohenjo Daro in India (3000 B.C.). The dye, alizarin, is present in the plant combined with a sugar and must be freed in order to dye, which makes the process quite complicated. The color is called Turkey red and is very stable once it is applied.⁶

The most important red colors, in part because of its brilliance and colorfastness, were dyes obtained from insects. Kermes, a dye obtained from the insect Kermococcus vermilio, that lives on the kermes-oak in the Mediterranean and the Near East. This dye was used in pre-history. It has been found in the Neolithic grotto of Adauste, France. During the Greek period of

4 Berlin and Kay (1969: 17-21, 25-28) have studied color terms in the languages of the world. They find that there is a regular pattern in the colors that are distinguished as complexity increases. Universally, as a minimum, languages distinguish "light" from "dark", but, when languages recognize a third hue, that color is red.

5. To dye hair with henna, which can be obtained in a red or a black shade, the dye is applied together with vinegar to control the acidity and an egg. This mixture is left in place for four hours before rinsing.

6. To dye Turkey red cotton cloth is mordanted by first soaking with rancid olive oil containing lime, treating with a solution of aluminum sulfate and finally steamed. The mordanted cloth was treated with the dye as a fine suspension. The early process required a complicated set of operations requiring up to four months. The natural product was quickly abandoned after synthetic alizarin was first produced in 1868. An iron mordant can produce violet colors.

Egypt, kermes was used as a vat dye using alum and urine to mordant wool, leather, and silk. The Mesopotamians discovered how to dye scarlet. The scarlet cape found by the Hebrews who conquered the city of Ai in 1400 B.C. (Joshua VII, 21) was dyed with kermes (Baranyovitz 1978). It remained a luxury dye that was used to prepare the scarlet cloaks of high military officials (Forbes 1964: 105). During medieval times, Venice was famous for producing the best colors. Their most famous color was "Venetian scarlet" made from kermes, which they called "vermilion" (little worm) hence the word, vermilion. Venice strictly controlled both the production process and the quality. Dyers in who used the cheaper madder as a substitute for kermes had to pay a stiff fine and/or their right hand could be cut off (Baranyovitz 1978). A second insect dye, lac, comes from the insect, Coccus lacca, that lives in various trees native to India and southeast Asia. The insects attach themselves to twigs and become covered with a viscous fluid that hardens to a shell. These twigs are extracted with hot soda (calcium carbonate) solution and provide shellac, which is now the more valuable product, and the dye, laccaic acid. Lac was the principal red color for dyeing silk in China, and in Asia generally. Lac was imported into Europe and Egypt beginning with the Christian Era.⁷

When the Spanish landed in Mexico they were very impressed with the quality of the Aztec dyeing industry and particularly with the vivid red color obtained from the insect, Dactylopius coccus. The insect lives on cactus (Opuntia sp. nochtli in Nahuatl, preferably O. cochinillifera). The insect was called nocheztli ("cactus blood"), and was carefully cultivated because the female cannot move and the insect must be spread by hand to get the maximum production. Farmers would take cactus leaves with the insects on them into their houses to protect them as breeding stock over the winter (Baranyovitz 1978). Cochineal was an important component of the tribute paid to the Aztec Emperor. Tribute rolls such as the Mendoza Codex depict the substance as white bags with red spots, the tribute amounted to over ten tons of dry dye per year. The Spanish rapidly expanded the cultivation of cochineal in order to export it to Europe. From pre-Columbian times until today, Oaxaca has been the principal source for this insect. In 1575, Spain received 7,000 arrobas (175,000 lbs) of cochineal, which exceeded the local demand and could be re-exported. By 1736 the amount had reached 875,000 pounds (Donkin 1977: 37). No other product apart from the precious metals, gold and silver, had as much monetary value and brought in as much revenue. The trade in cochineal was a Spanish monopoly and there was an absolute prohibition on exporting live insects from the New World. The Spanish even concealed the nature of the source of the dye pretending that it was a plant material. The French and the English tried several times to smuggle live insects out in order to set up a competing source but were not successful, and the Spanish maintained their monopoly for 250 years. Cochineal could be adulterated by putting in chalk, or other appropriately colored minerals and the authorities had to be vigilant all the time.

The dye in cochineal is carminic acid, and amounts to about 10% of the dry weight which is a relatively large amount for an insect dye. The dye is prepared by drying the insects on mats in the sun, a process, which, if done properly, could take two weeks. This method produced the best quality dye

7. An interesting parallel in Mesoamerica is the insect, Llaveia axin, which produced a fat, axin (Nahuatl), aje (Spanish) that was much used medicinally by the Aztecs, and is still used in Mexican folk medicine. The insect also produces a red dye that is discarded. Aje has been and is used as a lacquer in painting gourds.

(silver cochineal). Alternatively, the insects could be killed with boiling water and then dried producing a brown or dull red powder. The dye can be extracted in either acidic or basic conditions. There is some speculation that the numerous urine collection stations that existed in Tenochtitlan were designed to supply the urine needed to dye cotton under basic conditions. The stability, or "fastness" of carmine is phenomenal. Textiles dyed in antiquity still retain their color after several hundred years. This stability is very much improved by the use of mordants such as alum (tlalxocotl "sour earth" in Nahuatl). Use of alum mordant produces a crimson color. Hernández (1959: vol. 1, 315) says that "A purplish color⁸ can be obtained from the nocheztli, but a times, depending on the mode of preparation, it is scarlet. It is exquisitely prepared if it is ground with an extract of the tree called tézhocatl⁹ and alum, and pressing the sediment that forms into tablets." After the introduction of lemons and oranges into the New World the juice of these fruits was used to make the dye mixture acidic. Mordanting carmine with tin produced a vivid scarlet color that eclipsed kermes in Europe. The "red coats" of the British army were dyed with cochineal up until 1954. Cochineal is still used today to color a wide variety of foods and drugs.

An important thing to keep in mind is that many of the natural products such as dyes or drugs that we find very useful were not produced with our benefit in mind. Most of these products are what is called "secondary metabolites," i.e. they are not building blocks, food, or essential metabolites for the species producing them. Very often, these materials are produced for defensive purposes. In the intense competition involved in evolution species that cannot avoid predators are not able to reproduce and multiply and will soon become extinct. Animals have a variety of defensive techniques-- speed (deer), armor (armadillo), ferocity (lion), size (elephant), camouflage (chameleon), or intelligence (humans). These techniques are not available to plants. They have to sit there and take it. A common defense technique is to produce chemicals that will sicken, repel, or kill potential predators so that the plant will be left alone to survive and reproduce. Many secondary metabolites serve this function. These chemicals are interesting to us because often they will have physiological functions that are potentially medicinal. This idea also gives us a clue about the potential of different floras as sources of medicines or useful products. The more potential, or actual predators, the stronger the chemical defenses that a plant or animal species (because animals also do this, for example monarch butterflies or Costa Rican colored frogs) must be. Where would you prefer to search for potential medicines, Canada or Costa Rica if you knew that a single tree in Costa Rica has more different species of ants than all of Canada? The tropics have the biggest numbers of different species of animals and plants per unit of area in the world. This is why it is tragic that enormous areas of tropical forest are being irrevocably destroyed each year. Eisner, et al. (1980) found out that carminic acid happens to be a dye, but its real use to the Dactylopius is that it is very distasteful and repels ants that have the potential to harm them. Eisner also found out that a moth (Laetilia coccidivora), whose larva eats scale insects like cochineal, has adapted so well to carminic acid that it stores it and uses the acid to repel ants itself by regurgitating it on ants that threaten it.

8. Purple shades can be obtained by adding lime (calcium oxide) to the alum mordant in dyeing cloth.

9. Miconia laevigata. Hernández (1959: 2, 119) says that boiling water extracts a red pigment from the bark that was used as a paint because it adhered well to clay vessels and walls.

Dyes in Antiquity

Blue/Purple dyes

<u>Dye</u> <u>World</u>	<u>source</u>	<u>chemical</u>	<u>Egypt</u>	<u>New</u>
woad	<u>Isatis tinctoria</u>	indigo	mkrr	
indigo	<u>Indigofera tinctoria</u>	indigo	dr-nkr	
añil tlacehuilli	<u>I. suffructicosa</u>	indigo		
whortleberry	<u>Vaccinia myrtilus</u>	malvidin		
purple	<u>Murex trunculus</u> <u>M. brandaris</u> <u>Purpura haematoma</u>	6.6'dibromo- indigo		?
purple	<u>Purpura patula</u> "			?

Red dyes

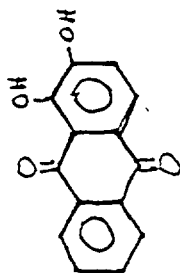
cochineal nocheztli	<u>Dactylopius coccus</u>	carminic acid		
kermes	<u>Kermococcus</u> <u>vermilio</u>	kermesic acid	dshr	
lac-dye	<u>Coccus lacca</u>	laccaic acid		
madder	<u>Rubia tinctorum</u>	alizarin	ip3	
alkanet	<u>Anchusa tinctoria</u>	alkannin	ns'.tjw	
henna	<u>Lawsonia inermis</u>	lawsone	pkrr	
	<u>Cosmos sulphureus</u> xochipalli	cosmetin		
dragon's blood	<u>Pterocarpus draco</u>	santalin		
logwood huitzquahuitl	<u>Haematoxylon</u> <u>brasiletto</u>	brazilin		

Yellow dyes

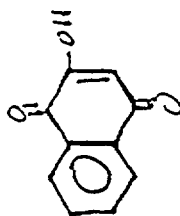
annato achiotl	<u>Bixa orellana</u>	bixin		
saffron	<u>Crocus sativus</u>	crocetin	-	

turmeric	<u>Curcuma longa</u>	curcumin	
zacatlaxcalli	<u>Cuscuta tinctoria</u>	cuscutin	
safflower	<u>Carthamus tinctorios</u>	carthamin	m3t.t
pomegranate	<u>Punica granatum</u>	tannin	inhmn
weld	<u>Reseda luteola</u>	luteolin	
dye's broom	<u>Genista tinctoria</u>	genistein, luteolin	
sumach	<u>Rhus coriaria</u>	fisetin	
persian berries	<u>Rhamnus infectorius</u>	rhamnetin	

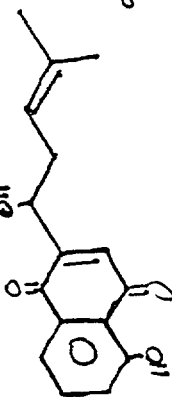
Dye formulas



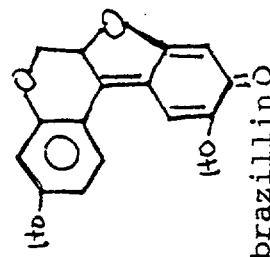
alizarin



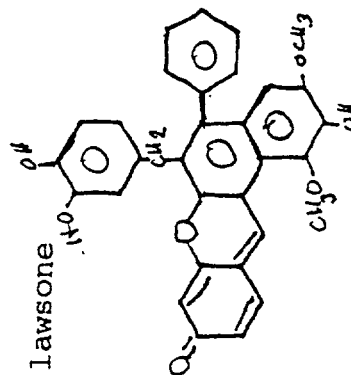
kermesic acid



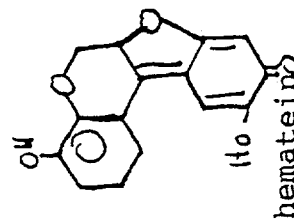
alkannin



santalín A.

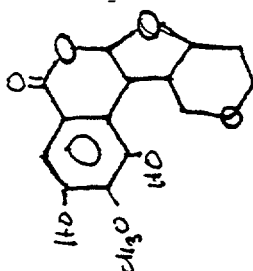


cuscutin

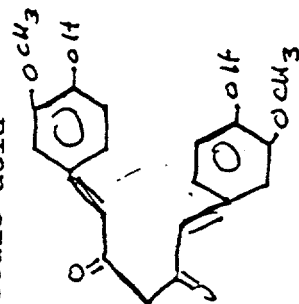


hemateins

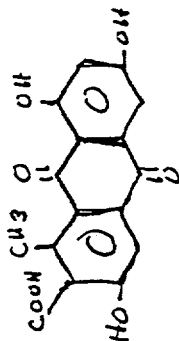
carminic acid



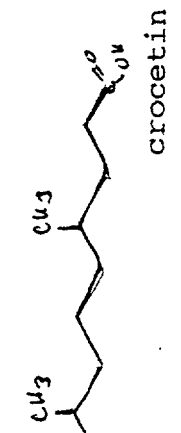
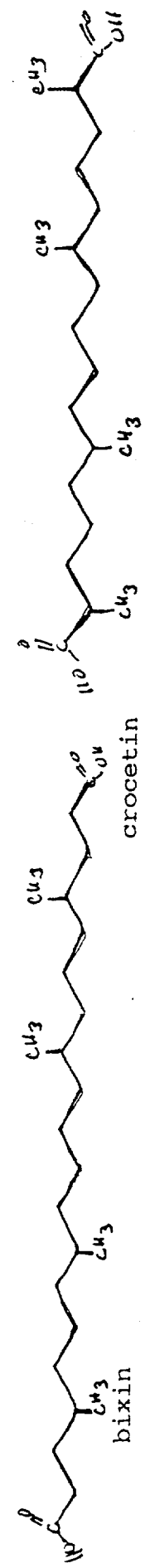
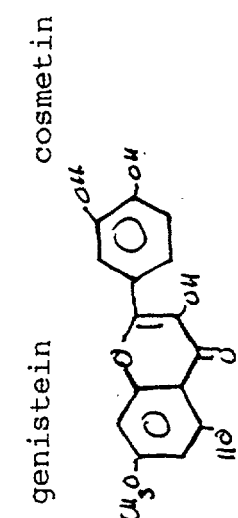
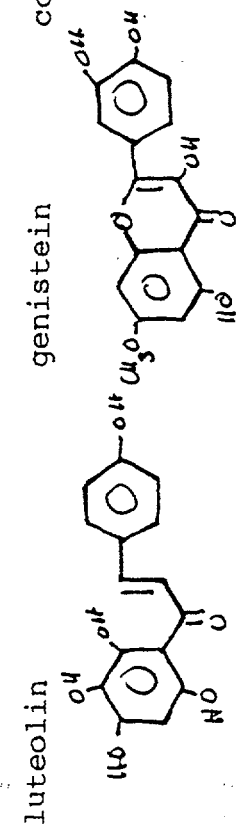
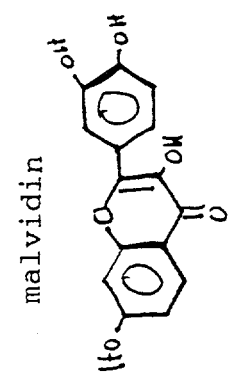
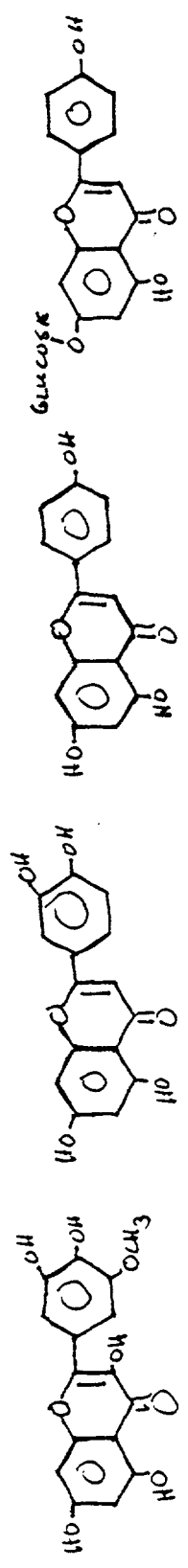
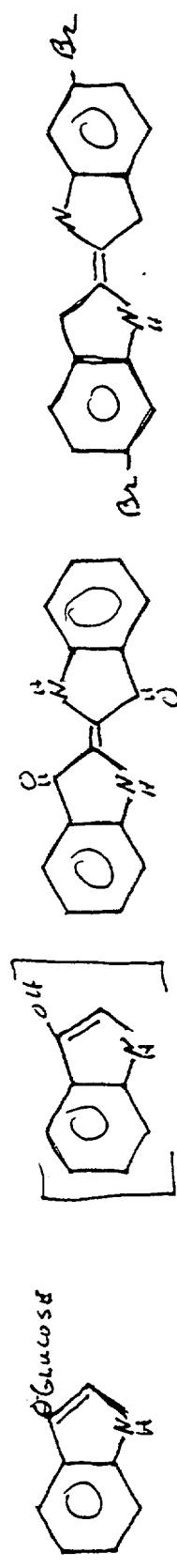
laccaic acid



curcumin



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Supplement and bibliography

Miscellaneous chapter

Huehuetlatolli are a way to humanize the subject, students can do skits based on these rules of behavior-- there are other huehuetlatolli available-- also riddles and sayings.

dyes and pigments. lots of hands-on possibilities. slides cochineal bugs, cochineal and painting from Florentine Codex, slides Natural History article re cochineal, can show tribute page from Mendoza with cochineal, show slides of Juxtlahuaca cave, Maya blue examples.

Maya blue preparation may involve interesting chemistry. Indoxyl (the soluble form of indigo) was the form used to impregnate attapulgitte prior to heating. This could have been done a couple of ways. Solid indigo could have been reduced and solubilized by boiling indigo with honey or sweet fruits (active compounds fructose or sucrose) and lime. The attapulgitte when immersed in the indoxyl solution and exposed to air would develop the blue color prior to being heated to about 100° C (boiling water) to make Maya blue. Littman thinks this is too complicated. More probably, the dye plant would be extracted into hot water directly and heated attapulgitte added to it. Subsequent exposure to air would form indigo and subsequent heating would form Maya blue. Decomposition of the indoxyl in the impregnated clay before heating could be accelerated by acidification of the mixture using plants with organic acids like acetic, oxalic or citric. although they are not necessary since air exposure will suffice eventually. Whether this acidification was done is unknown.

Visuals: slides of cochineal on cactus, images in Florentine of cultivation of nocheztli, Codex Mendoza cochineal tribute, grinding of cochineal, fixing acidity with lemons, dyeing with cochineal, Florentine pages on dyeing, Egyptian mummy dyed cloth, British red coats (dyed with cochineal)

For practical experiments students can play around with noticing the color changes from edible substances as the pH varies. (R. Mebane and T. R. Rybolt, 1985. "Edible Acid-Base Indicators," J. Chemical Education 62 (4): 285. The authors provide a table with the different shades from pH 2 to 12, but kids could do just plain water, ammonia and vinegar and see what happens. The grape juice is diluted to desired lightness with distilled water. Other materials, chopped solids in beaker, barely cover with distilled water, heat just below boiling point for 40 minutes, diluted as needed.

indicator	pH		
	acid (4)	neutral (7)	base (9)
red apple skin	orange	yellow-green	yellow-green
beets	bright red	changing	purple
blueberries	bright red	green	green
cherries	orange	brown	green
grape juice	red	green	green
plum skin	red-purple	changing	green
radish skin	bright orange	purple	brown
tomato	colorless	yellow	dark yellow
try your own			

Delena Tull 1987. A Practical Guide to Edible and Useful Plants. Austin: Texas Monthly Press has detailed instructions for dyeing wool and cotton fibers with a variety of natural dyes including cochineal. Students could use these techniques to experiment with the different colors produced with different

mordants. Most mordants are toxic so that caution and supervision must be done in these cases.

plant	mordant				
	aluminum	copper	iron	tin	none
cochineal	dark pink	maroon	deep blue	red	red
turmeric	gold	mustard	brown	gold	light gold
beets	yellow	light green	green	light yellow	white
cranberries white		pale green	brown	purple	light pink

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Appendix 3

I. Biological area

1. Biology of Corn (Tina, Mercedes)
2. Chinampa cultivation (Tina López)
3. Desert Plants Unit
 - a) Cactus and CAM metabolism (Helen Minerva)
 - b) Mesquite and its uses (Helen and Minerva)
 - c) Properties and character of Agave (Helen and Minerva)
4. Natural dyes (Helen and Minerva)
5. Spirulina and photosynthesis (Tina)
6. Aztec wounds and diffusion into cells--model
constructivist lesson (Bernard)
7. Nutrition, required nutrients, and foodways-- lesson and model
workshop (JoAnn Montes)
8. Demonstration lesson on constructivism-- plants and
photosynthesis (Diana)
9. Crickets and snails (Mercedes)
10. Life cycle of insects (Berta, Martha)

II. Earth science

1. Earthquakes in Mesoamerica (Martha, Berta)
2. Volcanoes in Mesoamerica (Martha, Berta)
3. Sedimentary rocks of Mesoamerica (Martha, Berta)
4. Geology and Geography of Mesoamerica (Martha, Berta)
5. Relief Map of Mesoamerica (Martha, Berta)
6. Mohs hardness scale (Martha, Berta)
7. Soil study (Martha, Berta)
8. Soil Porosity (Martha, Berta)
9. Testing soils for planting (Martha, Berta)
10. Plate Tectonics (Martha, Berta)

III. Miscellaneous

1. Physical science
 - a) moving Olmec monuments (Berta)
2. Puzzle on Aztec culture (Helen)
3. Pigments and paints in Mesoamerica (Martha, Berta)

Appendix 4

July 24, 1996

B. Ortiz de Montellano

Agave and Aztec Wound Treatment

Background information; The Aztecs were constantly involved in warfare and therefore had a lot of opportunities to treat wounds. Cortés and the other conquerors found out that the Aztec treatment of wounds was better than theirs and wrote as much to the Spanish king. After cleaning the wound and stopping the bleeding, the Aztecs dressed wounds with agave (maguey) sap or with honey to prevent infection. It is also interesting that the ancient Egyptians also used a mixture of grease and honey to treat wounds. Modern experiments in Argentina and Mexico have also shown that wound can be treated with table sugar with similar results.¹⁰ The reason why this treatment works is because we can consider bacteria as little bags made from a semipermeable membrane containing the cell components in a water solution. Oversimplifying, semipermeable membranes allow some molecules to pass (usually) while preventing large molecules from passing through. When two solutions with different concentrations of dissolved molecules are separated by a semipermeable membrane they will attempt to equalize the concentration. This can be done by having small molecules, including water, flow through the membrane from the more dilute solution into the more concentrated solution. This process is called *osmosis*. In Aztec wound treatment, agave sap or honey is much more concentrated solution of large sugar molecules than the solution inside a bacterium. When bacteria are in contact with agave sap or honey, the water inside the bacteria is removed and the bacteria are killed preventing infection.

Grades K-3.

Objective Expose students to fact that an egg is a cell, that it has a membrane that is different from the shell, and that things go in and out of cells.

Experiment 1: membrane in egg

Teacher strategy. Discuss with students what they know about eggs and/or cells. Desired answer: cells are in soft living things, and an egg has a hard coat rather than a soft membrane like in plants or animals. Question-- let's do some experiments and see.

Materials

fresh eggs

hard boiled egg (boil 5 minutes and plunge into cool water)

Procedure

Crack fresh eggs attempting to have students see inner membrane stuck to shell. Discussion-- hard to see membrane. Question--how could we see this better? Discussion may be inconclusive. Question what would happen if we boil the egg?

Crack and peel boiled egg (if done right, membrane can be seen) Question What

¹⁰. For details and references refer to Ortiz de Montellano's chapter on Aztec medicine.

if we could get rid of the shell without breaking the egg?
 Carry out the naked egg procedure below. And show the membrane to the children. Discuss that this is a very unusual cell because it is big enough to see because most cells are too small to see with your eyes.

Experiment 2: Water into cells

Teaching script: Demonstrate the experiment and have students feel the difference between the potato slices.

Materials

salt
 shallow bowls/ beakers
 fresh 1/4" slices of peeled potato

Procedure

put 1 cup of water in the beakers

stir in salt in one bowl and label it; leave one bowl with pure water as a comparison

place three slices of potato in each bowl

at 10 minute intervals take out one slice from each bowl and test for flexibility.

Question--What do you think will happen if we put chips that have been in salt water into fresh water? **Expected answer--**

rinse and put the slices from salty water into pure water

wait one hour and again test the results

results The potato slices in salty water will be limp, while those in pure water remain crisp; the effect is reversible.

Discussion. Question-- what did we just see? What do you think happened?

Expected answer-- slices in salt got soggy and ones in water did not, effect could be reversed somewhat.

Experiment 3

Grades 4-8

Objectives: To learn that molecules move in and out of cells; to learn about semipermeable membranes; to learn about the use of models in science.

Teaching strategy

The object of this unit is to get students to think about and devise ways to see the process of molecules moving in and out of cells. Activities are listed that 1) show the flow of water out of a cell, 2) show the flow of molecules into a cell, 3) prepare a semipermeable membrane from an egg, 4) show a model of how a bacterium would be killed by osmosis. Each activity uses the knowledge gained in the previous activity. Students should brainstorm about possible ways to do experiments rather than be told how to do the activities.

This unit can be done with students at different levels, but the depth of the brainstorming questions and of the conclusions to be reached would differ according to grade level. Although teacher scripts and questions are structured to lead logically from one activity to the other, and "expected student answers" are provided, it is very important that "student answers" that differ from the expected be discussed seriously and that experiments to test them be tried because just as much science can be learned from failed experiments as from those that are successful.

Experiment #1 Osmosis

Teacher script: Get the class to discuss in groups, and then report to the others on their conclusions some of the following questions-- What do cells (plants, and animals) need to live? How do you think that cells (bacteria) get their food and get rid of their waste? If cells are placed in water, why don't all the insides leak out? How could we find out?

Desired answer: Put cells in pure water and water with something else and see what happens.

Materials

salt
shallow bowls/ beakers
fresh 1/4" slices of peeled potato

Procedure¹¹

put 1 cup of water in the beakers

stir in salt in one bowl and label it (perhaps students might want to see what happens with different amounts of salt in the water. If so use several bowls with 1 to 3 teaspoons of salt).

leave one bowl with pure water as a comparison

place three slices of potato in each bowl

¹¹ These quantities and directions will produce the desired results, but it is important that students be allowed to propose and test variations. For example, potato slices could be peeled or unpeeled, slices could be thicker or thinner, the amounts of water and salt could be different-- the important thing is to measure and record the information. Students might want to extend the experiment to use other sliced vegetables or plants, or even use other liquids such as soda pop (have them compare diet soda, which has no sugar with the regular brand).

at 10 minute intervals take out one slice from each bowl and test for flexibility. **Question--** Do you think that we can reverse the effect? How would we do it? **Expected answer--**let's do an experiment, put a chip that has been in salt water in pure water

after 30 minutes rinse and put the slices from salty water into pure water

wait one hour and again test the results

results The potato slices in salty water will be limp, while those in pure water remain crisp; the effect is reversible.

Discussion

Students should be asked to hypothesize what happened. They should be encouraged to both write and draw pictures of their results. **Desired answer--** water goes out from potato slices in salty water. There should be a relationship between how fast the slice gets soggy and the amount of salt in the water. **Desired answer--** the bigger the difference in concentration of salt between the inside and the outside the faster the water leaks out of the potato. **Teacher question--** Do molecules only move one way--out? Is water the only thing inside the potato slice? Why don't other things inside the potato leak out? How could we find out?

Desired answer. Maybe there are big things inside the cell and they can't get out. Can we do an experiment putting a cell with big things inside in water? Could we put the concentration inside the cell so that water will come in, not out?

Experiment 2 Osmosis in

Teacher script

Tell class we are going to use a model. Scientists often use models that will imitate the real thing so that we can investigate a question or puzzle but are simpler to handle. We will use a sandwich bag as a model of the semipermanent membrane in real cells. If students have prior knowledge that starch is large molecule and that it turns blue with iodine, proceed with the experiment; if not, either tell them or do the starch and iodine experiments in this manual.

Materials

plastic sandwich bags
twist ties
tincture of iodine
cornstarch
two 500 ml beakers or cups
eye dropper
tablespoon

Safety: iodine is poisonous so that it should be treated carefully

procedure

fill one beaker half-full of water and add 25 drops of iodine
fill the second beaker with water and add one teaspoon of cornstarch. Stir to dissolve.

Put half of the cornstarch mixture into a sandwich bag and close it with the twist tie. Rinse off the outside of the bag in case some starch spilled.

Add 5 drops of iodine to the remaining cornstarch solution

Place the bag in the beaker containing water and iodine, and start timing and observing what takes place.

Results: The cornstarch solution will turn black as soon as the iodine is added. In about 5 minutes, the cornstarch solution in the bag will start to turn black, but the iodine containing water outside will remain clear.

Discussion: Have your student try to explain their observations in writing and pictorially. Desired answer-- cornstarch and iodine turn blue, therefore, iodine went through the membrane (baggie) into the cornstarch. However, the starch did not go through the membrane into the cup because it remained clear. Therefore, our model cell allows small molecules to pass but not big molecules. Also, the concentration of cornstarch was higher inside the baggie, therefore the flow of water and iodine was into the cell not out of it. This is the opposite of the potato experiment. **Teacher question--** If the bacteria that infect wounds are cells with semipermeable membranes like the potato example, what kind of thing could one do to kill them and prevent wounds from getting infected? **Desired answer--** put them inside or in touch with a concentrated solution of something so that they will lose water and get limp (or die). **Note--** Students may answer to use a concentrated salt solution, this is a valid answer but would probably be painful. In fact, however, sea water was used to treat wounds in the Spanish Civil War. If students have difficulty, they could be given a hint that the Aztecs and the Egyptians used honey, or its equivalent, agave sap, for wounds-- honey is a concentrated solution of long sugar molecules.

Experiments 3 and 4 The naked shrinking egg

Teacher script

Tell students that bacteria are too small for us to see so that we are going to use an egg as a model of a bacteria, since an egg is a big cell. **Question** Why do you think that an egg might be a good model of the semipermeable membrane in a bacteria? Why or why not? **Desired answer--** hard eggshell is not a good model (experimentally could put in water and see if it swells or shrinks as a test). **Question--** what could we do to an egg to make it a better model. **Desired answer--** remove the shell.

Materials:

one raw egg
wide mouth jar with lid
clear vinegar
flexible measuring tape

Procedure:

Measure and record the appearance and the circumference around the middle of the egg.
Carefully slide the egg into the jar without cracking the shell.
cover the egg with vinegar and close the lid.
Observe what happens and repeat periodically for the next 3 days
Take out the egg carefully, observe its appearance and measure its circumference.

Results: Bubbles appear from the eggshell and after 72 hours the eggshell is gone. The egg is covered by a transparent rubbery membrane (the semipermeable membrane) and it is bigger.

Discussion: The vinegar has reacted with the eggshell as shown by the bubbles and the disappearance of the shell. If the students have already done the unit

on rocks and minerals, remind them that acid reacted with limestone that is calcium carbonate (CaCO_3) and perhaps they could conclude that eggshell is the same. **Extension**--Students could be asked to go to a drugstore and find out where the calcium in calcium pills comes from. **Question**-- what is keeping the egg together? **Desired answer**-- a membrane that is a model of the in a cell. **Extension by students**-- perhaps an egg is a cell covered with a hard coat as well as membrane? **Question**-- if this is a semipermeable membrane, and remembering what you know about semipermeable membranes, why is the egg bigger? **Desired answer** because the inside of an egg is more concentrated than vinegar and therefore water went into the egg like it did in the cornstarch baggie.

Teacher script. **Question**-- now that we have a model bacteria, and remembering what we know about semipermeable membranes, what could we do to shrink or kill the bacteria? **Desired answer**-- put egg in a more concentrated solution so that it will lose its water.

Materials

naked egg from activity 3
jar with a wide mouth
corn syrup, or honey diluted half-and-half with water, or agave sap
(obtainable from ----)

Procedure

Pour 4 inches of syrup, honey, or agave sap into the jar
Carefully slide the egg into the syrup until it is covered
close the lid and leave undisturbed for 72 hours.
Compare appearance of the egg before and after its immersion in the syrup

Results: The egg has lost its shape and shrunk a lot, losing most of its contents.

Discussion. As students predicted, the water in the egg went out through the membrane leaving a sad remnant behind. If this had been a bacteria it would not be functional.

Assessment: Knowledge after the unit should be compared to the discussions by students at the beginning of the unit. Students should be able to 1) explain that things go in and out of cells through semipermeable membranes that allow little molecules to pass but hold large molecules back; 2) that water flows from the less concentrated side to the more concentrated side; 3) that scientists use models that are simpler than the real thing but that are easier to handle.

Extensions/Applications:

High School

Have students do microbiology experiment below.

Middle school

Get a resource person to repeat procedure in Davidson, J.L. and B. R. Ortiz de Montellano, " The Antibacterial Properties of an Aztec Wound Remedy," Journal of Ethnopharmacology, 8 :149-161 (1983). This would involve growing non-pathogenic bacteria on agar in petri dishes and showing the zone of growth inhibition (i.e. where bacteria do not grow) around a filter paper disk impregnated with honey or maguey sap.