Addressing Student Misconceptions about Reproduction and Heredity
Classroom Based Research Project

Education 545-631: Leadership for Middle Level Science
University of Pennsylvania
April 21, 2007

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ABSTRACT

At times, misconceptions can become a difficult barrier to overcome in a classroom because some students are unable and sometimes unwilling to deconstruct their preconceived notions and accept new ideas. Yet, planning to address misconceptions using specific methods of teaching, such as the inquiry method, may in fact help students deconstruct and accept new ideas. This hypothesis was based on prior experiences with inquiry learning and current scientific research. Therefore, a research study was constructed and implemented using the inquiry-based approach to learning in order identify and address student misconceptions, specifically concentrating on notions about reproduction and heredity.

In order to begin, an understanding of what students knew was gained through research and data collection. The teacher researcher examined common misconceptions about heredity and formulated open-ended questions directed toward selected students’ own ideas. Using four students, each was pre-assessed on genetics using an open-ended assessment. Then, inquiry activities were implemented into daily lessons. Finally, students were re-assessed using an interview model to assess results of the study. Based on data, the study was successful at addressing some misconceptions about genetics and ascertained the use of inquiry-based methods as effective with helping students deconstruct and accept valid scientific explanation.

BACKGROUND

Identifying misconceptions becomes more prevalent when teaching science to middle school children. By the age of 10 years old, students should have had a multitude of positive experiences in science education. This then directs students onto science and wanting to know how and why things work. Yet, if students do not receive the answers to the hows and why’s, they seemingly begin to develop their own ideas about the way things occur. As an educator, one may find it to be a very difficult barrier to overcome many students’ misconceptions about scientific phenomena and perhaps more importantly how to change their points of view. More specifically, the question that this study is based on is: what will happen to student understanding of science concepts about reproduction and heredity when their misconceptions are addressed through inquiry based methods? The objective for this study is to determine whether or not the inquiry based approach to teaching and learning impacts how specific students perceive scientific concepts.

In order to gain answers to this question, the teacher researcher conducted a complete and thorough investigative study that was designed to address student misconceptions about reproduction and heredity. Four 6th grade students, who have specifically demonstrated a wide array of scientific misconceptions thus far in the school year as determined by teacher observations and classroom tests, participated in the research investigation. Of the four, two students were male and two students were female. All students in the study range in ages 11-12 years old and attend a Charter School in the Northeast section of Philadelphia. Throughout the study, the researcher will refer to the participants by letters A through D in order to protect their privacy and keep information confidential. (In order to protect the privacy and confidentiality of these students, ethnicity and socio-economic status are being kept private for legal purposes).
Students were recruited for the study using the student and parental consent forms devised by the University of Pennsylvania Science Teacher Institute [Penn STI], which were explained and distributed in class by the teacher researcher. Moreover, students were made aware through verbalization and written documentation that this study is for research purposes only and would not affect their grades in any way. It is stated on the consent forms that the students may withdraw at any time throughout the study if they so chose.

The classroom environment was conducive for inquiry-based learning throughout the duration of this study. Students were seated in groups four and six and materials were easily accessible. Based on prior investigations throughout the school year, students were familiar with the inquiry-based procedures to learning science. So, students were well-prepared for this style of learning.

**LITERATURE REVIEW**

Misconceptions are often defined as ideas that persons believe to be true but do not necessarily match scientific evidence (Hanuscin, retrieved January 17, 2007). One of the very first steps in conducting a classroom based research project is to research current information about one’s topic. For this particular study, it was beneficial for the teacher researcher to learn about some common misconceptions that middle school students have about reproduction and heredity. In addition, it was valuable to gain a better understanding of how children process scientific information and learn about the best practices being implemented into the science classroom to get students to deconstruct misunderstandings about science. In preparation for this endeavor, some current research studies have been outlined in the following paragraphs.

As it pertains to science education, research studies are very much alike when examining how students’ perceive scientific concepts. Most researchers agree that learning is a process which takes careful planning and time, both which greatly impact a child’s perception of concepts. Researchers from the Missouri Department of Elementary and Secondary Education (2005) state that one of the first steps to creating scientifically literate citizens is to identify their preconceived notions about science. In their research, they created a list of reasons why students might develop misunderstandings about science. The list ranges from factors such as there is not enough time allotted to absorbing the information, to prior experiences, to not making connections to everyday life, all the way to everyday terminology interfering with conceptualization, which causes confusion (*Misconceptions in Science, 2005*). In other studies, specialists concur that using “causal” questioning is an effective tool in helping to identify students’ preconceived notions. Causal, or open-ended, questioning can be defined as a strategy that is used to provoke student thought which in turn allows the researcher to identify misunderstandings and the ideas behind them ("Modeling for Learning," 2002-2007). In fact, one graduate student researcher from the University of Montana conducted a classroom based research project similar to the present study and used causal questioning as both her pre- and post-assessment source of data analysis in identifying student misconceptions with genetics. Her results stated that her students obtained greater understanding of genetics on in-depth level but decreased time spent on other topics, which coincides with the above mentioned time constraints (Beale, 2003).
Once teachers are able to address misconceptions, research suggests that educators provide opportunities for students to change their own views so that they may accept new and valid scientific explanations. Unfortunately, this is not always feasible in the daily classroom. Teachers are rarely addressing misconceptions, which may be due to the fact that they are unaware of student’s prior knowledge and do not know how to address or identify them or they think that sharing the correct ideas with the students will automatically make students think otherwise (McComas, 2005). In their defense, teachers have little time to devote to classroom based research on their own and lack the necessary tools for conducting such research. In addition, educators are limited in their opportunities to share their results and findings with colleagues and specialists (The Nature of Science, 1993). Overall, this is highly ineffective for getting students to alter their own ideas and accept unfamiliar ones. Rather, constructivists, like Bruce Watson and Richard Kopnicek of Phi Delta Kappan, suggest that teaching for conceptual change is valuable when confronting children’s experiences (1990). The study reported by Watson and Kopnicek promotes that children and how they learn should be the main focus of the teaching of any subject. It supports and acknowledges that students and teachers need to overcome barriers such as the unwillingness to let go of ideas. As well, it outlines Lev Vygotsky’s “Zone of Proximal Development” where students learn at their own pace and ideas cannot be forced on them when they are not yet ready to accept them as valid information. In addition, Watson and Kopnicek offer three ways to promote new thinking patterns: make connections to everyday life, allow students to make hypotheses and investigate on their own, and stress consistency with the children (1990).

As educators move towards changing student thinking, researchers have developed a planning method to help students deconstruct their preconceived notions about science. The learning cycle method encompasses five areas of daily planning which has been designed to help teachers develop engaging, meaningful activities in the classroom. They are: Engage, where teachers pre-assess students and identify any misconceptions; Explore, where there is minimal teacher directed activities and where students work together to test out hypotheses; Explain, where students explain their results in their own words and provide definitions and terminology as well as alternative models; Extend, where students apply what they know from their investigations using explanatory terms correctly; Evaluate, this is ongoing throughout learning and obtained through observations of students applying new information and a change in thinking patterns (Lorsbach, retrieved January 17, 2007).

In reference to the present study, the teacher researcher explored some of the most common misconceptions which students possess about reproduction and heredity. They can be found listed by two sources in Appendix A of this report.

Overall, student misconceptions are a difficult barrier to overcome within a science classroom. Recent studies conducted about this topic report that it is highly effective for educators to identify these preconceived notions so that they can provide learning opportunities for students to alter their own ideas in order to accept scientifically valid explanations. Students should be provided time for investigation and processing as well as opportunities to make connections to everyday life. Students should be taught to change their minds not fill their minds (McComas, 2005).
METHODOLOGY

To begin the study on determining what will happen to student understanding of science concepts about reproduction and heredity when their misconceptions are addressed through inquiry based methods, the teacher researcher obtained a broader perspective of various types of misconceptions students encounter when learning about reproduction and heredity (see Appendix A). Once compiled, the teacher researcher could begin to compare the results of other middle school aged children with that of her own students’ results.

Initially, students were asked a series of open ended questions about their ideas on how traits are passed from one generation of offspring to another (see Appendix B). They responded through written explanation, which were used as a source in data collection. Students then participated in inquiry based learning activities designed specifically to address their individualized preconceived notions about reproduction and heredity. A more detailed description follows in the next section of this report.

The factors that remained constant throughout the research study were the number of students surveyed, the questions asked, the scientific content being taught, and the time frame in which the study was conducted. The factor that was intentionally manipulated for the study was the inquiry based method utilized for teaching the participants throughout the unit. The observable factor that changed throughout the study was the students’ conceptions about reproduction and heredity and their willingness to let go of their preconceived notions and accept new ideas.

Procedures:
1. Identify four students with a wide array of scientific misconceptions. (Choose 2 female and 2 male students with similar ages).
2. Conduct preliminary research on student misconceptions about a specific scientific concept that may become easily misunderstood. For this particular research plan, gather information on how students perceive reproduction and heredity on a middle school level.
3. Gain consent for participation in the classroom based research project from both students and parents.
4. Discuss with students the purpose of the investigation and distribute a series of causal questions about reproduction and heredity to the students. Students should respond to questions using a written format.
5. Teacher will then develop inquiry based activities for teaching reproduction and heredity based on the determination of misconceptions held by students on the pre-assessment. All students should be taught using consistent activities in order to keep data valid and reliable.
6. Students will be assessed throughout the unit by means of teacher observations, summative exams, interviews, and authentic tasks.
7. Teacher will re-examine the initial open-ended questions and ask students to answer them again. This time, students will be videotaped as they explain what they know about reproduction and heredity.
8. Teacher will compile results of the study and draw conclusions based on observations, student responses, assessments, secondary data sources, student work and interviews with students.
Moreover, students were assessed throughout the study using teacher observations, written and verbal assessments, interviews, as well as performance based tasks, where students completed activities and were assessed on their abilities and understanding of the concepts. All of these strategies were used in compiling a complete and thorough collection of investigative data.

Overall, most data was collected qualitatively into descriptive, narrative accounts of the results of the classroom based research project. The qualitative data analysis was in the forms of observational notes, interviews, and video-tape and secondary data sources from pre-existing research. Some data, however, will be a bit more quantitative in nature such as the survey/questionnaire and student work. The data gathered throughout the study is listed in more detail in the next few paragraphs.

In terms of qualitative data collection, observations for this study were conducted through systematic record keeping and mindful/careful watch of behaviors and interactions among participants both verbally and non-verbally. Making observations afforded the teacher researcher the opportunity to witness “actual” student responses in addition to students reporting their perceptions about a specific concept during both formal and informal interviews.

As well, preliminary research is an important part of data collection. The information gained from previous studies on student misconceptions about scientific concepts allowed for comparative analysis of results from previous studies in accordance with the current study’s results.

Another type of quantitative data, such as the survey/questionnaire, allowed for relatively quick data collection. The questionnaire being used elicited open-ended responses, where students were able to explain their ideas and reasoning. At that point, analysis of the data revealed unexpected results and responses. This can prove to be a very useful tool when examining student misconceptions because it allows students the opportunity to express their reasoning skills behind their own misconstrued ideas.

Any tasks/student work completed by the students in reference to this particular study were useful in analyzing if different methodologies aid in addressing student misconceptions about reproduction and heredity.

As students continued throughout the study, the teacher researcher revisited their initial conceptions about the topics. At that point, she analyzed the data collected and drew conclusions based on the driving question for the research based classroom project.

**FINDINGS**

Analyzing data is a key component when researching how children think about a specified topic. The data gathered was based on student responses to a series of open-ended questions and inquiry-based activities pertaining to reproduction and heredity, specifically genes, DNA, and how traits and characteristics are inherited throughout generations. The initial pre-assessment was given on March 1, 2007 at the beginning of a class period. Students had not read, nor participated in any activities relating to reproduction and heredity prior to the pre-assessment during this school year. Some students in the study used more explanatory terms, while others answered either without supporting the reasoning behind their thoughts or were unable to answer at all. The chart listed below outlines some of the student responses. (see Appendix B for list of questions asked).
March 1, 2007 Pre-Assessment

<table>
<thead>
<tr>
<th>Question</th>
<th>Student A</th>
<th>Student B</th>
<th>Student C</th>
<th>Student D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inside DNA, chromosomes, during reproduction</td>
<td>Inherited characteristics by genes</td>
<td>Inside chromosomes when daughter cells copy</td>
<td>Inside cell in nucleus</td>
</tr>
<tr>
<td>2</td>
<td>Traits are physical and characteristics are how people act</td>
<td>no response recorded</td>
<td>traits are passed down and characteristics are features</td>
<td>50% from each parent creates a blend of a new trait</td>
</tr>
<tr>
<td>3</td>
<td>Traits come from ancestors because genes are transported between them</td>
<td>no response recorded</td>
<td>Get traits from family because they had traits</td>
<td>50% from parents is equal to half the traits from each parent</td>
</tr>
<tr>
<td>4</td>
<td>True; everyone I met looks like their gender-like parent</td>
<td>no response recorded</td>
<td>False; mothers have XX and father have XY</td>
<td>False; It's a 50/50 split evenly</td>
</tr>
<tr>
<td>5</td>
<td>The grandparents might have had blue eyes and the grandchild might have had the gene.</td>
<td>no response recorded</td>
<td>Two parents with same eye color makes offspring with different</td>
<td>One of the parent must have had blue eyes or another family member</td>
</tr>
</tbody>
</table>

Based on the above data, it is evident that some of the students have a basic background about reproduction and heredity. Also, in some responses it is obvious that students have misconceptions about specific concepts. For instance, student A states that he believes, based on his own experiences, that females inherit most of their genes from the mothers, while boys inherit most of their genes from their fathers. This is a classic example of prior cases studies on how students develop misconceptions. Student A based his response on his own experiences and was satisfied with his matter of fact explanation. Similarly, for question five, student C had developed a pre-conceived notion that there was some sort of blending that occurred between the parents to produce an offspring with blue eyes. Research indicates that this student is confused by the process, which more than likely stems from poor teaching or a blending of facts. Moreover, in most of the responses, students attempted to use the scientific vocabulary associated with the unit; yet, they illustrated difficulties with using the terms correctly as indicated in prior research studies.

Throughout the unit, students engaged in inquiry based activities to aid in deconstruction of their misconceptions. They participated in one type of activity where each student was asked to simulate Gregor Mendel’s pea plant experiments and create their own pea plant by investigating how dominant and recessive traits are inherited. Students interacted at random with each other to choose alternate characteristics using trait cards. Students recorded their traits on charts and combined their alleles to determine the genotype and the expression of a certain phenotype of their offspring. Students then illustrated what they thought their plants should look like. In a later activity, after guided instruction on Punnett Squares, students were asked to reproduce their “offspring” plants with another plant (or peer) in the class. As they “cross-pollinated,” students worked out the probability or likelihood of certain genotypes and phenotypes to produce new offspring.
Based on teacher researcher observations and a collection of samples of student work, two out of four students in the study were able to accurately apply capital and lowercase letters to the recorded dominant and recessive alleles. However, student D had some errors when recording genotype letters. She combined different letters to symbolize dominant or recessive alleles to produce a genotype. On the other hand, student B was unable to complete the chart independently and sought assistance from peers and teacher researcher. As for the illustrating and calculating of the Punnett Square/probability activity, all students in the study were able to perform the task with accuracy.

Another type of inquiry activity was designed and implemented to allow students to mathematically work out how chromosomes are inherited from each parent so as to address one of the misconceptions set forth by B. Berthelson (1999). Before the activity started, students determined that females can only contribute an X chromosome during sexual reproduction based on the female genotype XX. Students assigned an X or a Y to each side of a coin. Next, they made predictions and conducted their own experiments by flipping coins to test the probability of inheriting either an X or Y chromosome from the father to determine the sex of an offspring. Each student recorded their responses into a chart and proved their hypotheses correct or false. In conjunction with research, proving their hypotheses to be wrong should help students to deconstruct and accept new ideas to be true. In this case, students were able to draw conclusions about the randomness behind inheriting an X or a Y chromosome; therefore, they were able to apply probability to human situations in families and not just genetics problems in school.

Three out of the four students were able to accurately write the genotype correctly and determine the percentages possible for gender assignment. Instead of writing the letters of the genotype, student B wrote the phenotype. This does show how the student understood that the end result of the coin-toss produced either a male or female offspring. Also, student B failed to calculate the final percentages of boy to girl ratio.

Other inquiry activities were implemented throughout the unit and produced similar results as the above mentioned. As the unit came to an end, the students were asked the same questions again as in the pre-assessment. This allowed the teacher researcher to draw conclusions based on the original research question: what will happen to student understanding of science concepts about reproduction and heredity when their misconceptions are addressed through inquiry based methods? The results of the post-assessment video-taped interview are as outlined below.

### April 16, 2007 Post-Assessment

<table>
<thead>
<tr>
<th>Question</th>
<th>Student A</th>
<th>Student B</th>
<th>Student C</th>
<th>Student D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inside chromosomes; during cellular reproduction chromosomes are copied and create genes which are smaller.</td>
<td>found in the nucleus</td>
<td>Inside chromosomes; I know because I paid attention</td>
<td>Found on the chromosomes. I know this because I know the parts of a cell.</td>
</tr>
<tr>
<td>2</td>
<td>Traits are physical/phenotype features and characteristics are how people act.</td>
<td>Traits are determined by characteristics and characteristics are models</td>
<td>traits are passed down and characteristics are features</td>
<td>Characteristic is straight or curly hair and trait is more specific like brown curly hair.</td>
</tr>
</tbody>
</table>
3

| Traits come from family. Some are carriers of some traits, while others are carriers of others. Some may be hybrid or dominant. This determines the way offspring look. | Get them from their parents | Get traits from family; they are determined by DNA | From their parents; they get the 23 genes from each parent. |

4

| False; both parents contribute an equal amount of genes and traits. Female gives X half and male gives either X or Y. | False; they both come from each parent | False; you get 50% of your DNA from each parent | False; no matter which gender you get 50% from mom and 50% from dad. |

5

| The parents are both carriers of the recessive blue eyed gene and the offspring inherited both recessive genes. | Someone else in the family has blue eyes | Parents are carriers of the trait | The blue eyes were probably a recessive gene from a grandparent. |

Based on the data chart above, it is evident that some students were able to deconstruct their misconceptions about specific concepts. For instance, student A changed his way of thinking on question number four. He altered his response from thinking it was a true statement in March to knowing it was a false statement in April. Likewise, student C altered her way of thinking about question five. She was able to change her thoughts about the “blending” of eye colors to knowing that the parents were carriers of a recessive allele. Student B was able to answer all questions on the post-assessment, yet still shows some misconceptions about the differences between traits and characteristics even after partaking in inquiry activities. Student D still expresses some confusion with question two. She understands that characteristics describe a broader term and traits are more specific; however, she is unable to convey this in her response. She should have said “an example of a characteristic is hair texture; while, the trait would be curly or straight hair.” Implications of this data for the teacher researcher are discussed in the conclusion section of this report.

**CONCLUSION**

Identifying misconceptions that students have gives insight about what they know about reproduction and heredity. Interestingly, it shaped a framework for how this concept needed to be addressed and taught as well as how to teach students to alter their previous conceptions and accept new ideas. Based on current research and the evidence set forth in this report, inquiry-based methods for learning are an effective tool in assisting students to alter their views. Like researcher Beale (2003), this group of students was able to gain a better understanding of the concepts being taught and as with many units of exploration in a classroom, there too was insufficient time to expand upon other topics.

The concept of reproduction and heredity is a difficult one to grasp. Middle school aged children have many misconceptions about this subject as evidenced in the research studies and the above data tables. As mentioned in the research, students base their knowledge on observable characteristics, prior knowledge, past experiences, etc. This concept holds true to this particular group of students. Research indicates that children develop ideas about science from their everyday experiences and those ideas are
adapted and expanded upon throughout formal science education. These children adapted their knowledge of heredity and applied it to what they previously knew from either their own experiences or what they had learned in past years through science education. This theory is evident with a response such as, “everyone I ever met looks like their gender-like parent.” This retort implies that this particular student knew that offspring inherit traits from their parents, but miscues how they get them.

The students with whom this study was conducted inform teaching in the general sense. They imply that middle school aged children have misconceptions about parts of the natural world. This affects education greatly in the sense that it reiterates that reform is needed to successfully educate students to understand and accept valid scientific explanations and become scientifically literate. A scientifically literate citizen possesses a deep understanding of scientific principles and theories/ideas. They are able to make real-life connections to scientific phenomena, such as why they are similar or even different from each other.

In general, research is still being conducted on a consistent basis in order to inform teachers and students about scientific occurrences. According to Krajcik, Czerniak, and Berger (2003), students should have a meaningful understanding of science. That is, learners should scaffold and make connections among scientific ideas and personal experiences or viewpoints. Moreover, students should be able to apply knowledge gained in a classroom setting to real-life as was attempted in the present study.

These findings enable educators to enhance the development of formal educational strategies. The results of this study allow teacher researchers some opportunities to gain insight into students’ preconceived notions about reproduction and heredity. Although students have difficulty restructuring their own ideas about genetics, the teacher researcher now has a better understanding of how to designate and expand instructional strategies that support students’ ideas about genetics. As an educator, teachers benefit by having a baseline assessment of student knowledge so as to effectively and formally teach scientific concepts to encourage students to become scientifically literate.

Although the present study showed some success in altering student ideas, there were some limitations. There is still a need to collect more information about how children learn scientifically. This is evident in the sample of responses gathered for this report. For instance, student B was unable to formulate a written response to the pre-assessment on his own. This data does not necessarily show a change in his viewpoints. It does, however, show learning since he was able to answer the questions in April. One influential factor leading to skewed data could be educational levels of the individuals in the sample. Students learning abilities should also be considered when assessing information learned. In addition, this study could also increase validity with a larger group of students in order to gain more insight into various misconceptions that students may have. Also, timing is always a factor when conducting research, so an improvement could be made by allotting more time to the study.

After assessing the findings of this study, it is evident that inquiry-based learning methods are effective in addressing some student misconceptions about reproduction and heredity. The four students in the study showed growth in at least one area of their thinking. Furthermore, using the information outlined in this report will assist in the
teaching and learning process. Educators will benefit by having a baseline assessment of student knowledge so as to effectively and formally teach scientific concepts using inquiry based methods in order to encourage students to become scientifically literate citizens.
REFERENCES


Appendix A: Common Misconceptions about Reproduction and Heredity:


1. Daughters inherit most of their characteristics from their mothers. Boys inherit most of their characteristics from their fathers.
2. Variation between species is a result of adaptation to environment instead of inheritance.
3. Sexual reproduction occurs in animals but not in plants.
4. Students do not distinguish between sexual and asexual reproduction.
5. Asexual reproduction produces weak offspring. Sexual reproduction produces superior offspring.
6. Students believe that transmitted characteristics are acquired during the life time of the animal.
7. Individuals can adapt to a changing environment. These adaptations are heritable.
8. Students do not understand the relationship between DNA, genes, and chromosomes.
9. Students can apply chance and probability to assigned genetics problems, but not to human situations in families.


- Students may believe that traits are inherited from only one parent or that environmentally caused characteristics may be passed on to offspring.
- The process of meiosis, as it relates to the structure and location of chromosomes is very complex.
- Most students require time and repeated exposure in order to comprehend all parts and steps of meiosis.
- Students may believe that recessive traits are rare and that dominant traits are the most common.
- Students over generalize that phenotype can be a visible trait.
- Students tend to overextend mathematical probabilities to predict the outcome of single events.
- Students assume that all inherited traits follow the examples of Mendel.
- Many students believe that characteristics acquired through the environment may be inherited or believe that learned skills and behavioral similarities (perhaps learned from parents) are inherited.
- Students confuse the movement of chromosomes and chromatids during mitosis and meiosis.
A common misconception is that all or many types of cells can undergo meiosis.

Appendix B

Please answer the following questions to the best of your ability and use complete sentences.

1. Where are genes found in cells? How do you know?
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

2. How are traits and characteristics different?
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

3. You have probably noticed that different people have different traits such as eye color, hair color, and different physical features. Where do people get these different traits from? Explain your reasoning.
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

4. Do daughters inherit most of their characteristics from their mothers, while boys inherit most of their characteristics from their fathers? Why or why not?
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

5. A child has blue eyes and both of her parents have brown eyes. Why is there a difference between parent and offspring?
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________