A COMPARATIVE STUDY OF THE SKELETAL AND MUSCULAR DEVELOPMENT OF THE SQUIRREL MONKEY AND HOW IT RELATES TO THE LOCOMOTOR PATTERNS BETWEEN THE INFANT AND THE ADULT

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Abstract

The composition of the body in relation to the distribution of skin, muscle, bone and other tissues is directly related to the activities the individual is capable of performing throughout its life stages. The infant squirrel monkey is born with 20.65% TBW devoted to muscle, 24.65% TBW in bone, 24.15% TBW in skin, and 24.7% TBW in other supporting tissues. The adult squirrel monkey tissue distribution changes to 41.0% TBW in muscle, 17.2% TBW in bone, 17.5% TBW in skin, and 24.6% TBW in other supporting tissues.

Consistently the adult demonstrates a tissue distribution and size that is compatible to living in the trees, moving through areas to forage, and the ability to escape predators that enter their preferred habitat. The infant demonstrates a body composition and size consistent with limited mobility and dependence on its mother for nutrients.

The trend in the change of tissue distribution through growth and maturation from infant to adult are demonstrated and explained in relation to activities at the various life stages of the squirrel monkey.

INTRODUCTION

What goes into making an organism and how that organism works throughout the life stages depends on the organization and function of the different, but related, body parts (Morbeck 1997). The various systems of the individual must work together at each level (cellular to whole organism) to allow the organism to grow and develop both physically and socially, to change or adapt as an individual (therefore as a species), and to reproduce in order to continue the existence of its species. The skeletal and muscular systems are two integrated systems that must grow, develop, and change in relation to the surroundings of an organism. These two systems provide a framework of protection for the other systems of the body and a means of survival through movement and load bearing (muscles pulling against bones connected through joints to produce movement and support weight), whether it be in the form of foraging, play, escape, or moving from one point to another within the preferred habitat of the organism. The systemic development of an organism is unique to its life history and its survival as an individual and as a species.

The focus of this research is found in two questions: (1) How do the muscular and skeletal systems function in order to allow the squirrel monkey to perform the various activities that it must in order to grow and survive in its selected habitat? and (2) Specifically, how is the transition from neonate to adult of *Saimiri boliviensis* important to its life? In order to discuss the changes in an individual, recognition that the total body weight (TBW) of an organism and the changes in that weight or distribution and composition of that weight is directly related to its ability to conduct itself in terms of survival. Survival includes the ability to grow, develop, and reproduce.

The body weight of each organism is the unique evolutionary product of five variables: (1) individual weight is an integral of biomass; (2) average adult weight varies among the species of a single genus; (3) weight is a variable of metabolism; (4) weight varies with age; and (5) a major proportion of weight underlies locomotor adaptation (Grand 1977).

The first variable takes the body weight of an individual and multiplies it by the number of adult individuals of a given species in a given area. This determines the approximate biomass concentration for a given area and therefore aids in determining the adaptability of the species in relation to the food chain within that area (Grand 1977).

Variable two explains that individual species within the same genus will differ in average body sizes (e.g., adult male *Macaca fascicularis* and *Macaca fuscata* and *Macaca nemestrina*, approximately the same weight; adult *Cercopithecus talapoin*, approximately 1/5 the weight of the adult *Cercopithecus ascanius* (Napier and Napier 1967)).

Variable three states that weight is a metabolic variable. Each organism consumes, digests, and uses energy in different ways according to what the demands of its environment are. Referring to variable one, an area of high vegetation can support a variety of herbivores without sustaining irreparable damage, providing the herbivores do not strip the vegetation of the reproductive or growing ability of the plants, as in sheep pulling grass up by the roots. Also, an area that contains a high number of herbivore species can support a limited number of carnivores since the metabolic demands of the carnivore are met through a high quantity but low energy diet. The above reference is to the energy pyramid that relates energy production and use to the various trophic levels found in nature, as in the producers (plants) contain the highest amount of energy available for growth and reproduction and will use approximately 90% of that energy for itself. They pass on approximately 10% of the energy produced to the next level of consumer (herbivore) which uses approximately 90% of the energy for growth and reproduction. The next trophic level consumes the herbivore and receives approximately 10% of its available energy for its growth and reproduction. The amount of available energy is constantly being reduced the higher the energy travels up the pyramid, therefore requiring a greater amount of material to be consumed at the highest trophic level (carnivore) in order to maintain the needed energy for growth and reproduction.

Variable four states that weight changes with age. The natural growth patterns of an individual allows for an increase in the weight of tissues and organs. Changes in weight are generally uneven in time, occurring in "growth spurts" (Grand 1977).

The focus of this project is with variable four and variable five concerning the changes in the proportion of weight between the infant (neonate) and the adult, and what changes occur in the locomotor patterns as a result. By focusing on the changes in body weight proportions, both skeletal and muscular, question one from above can be addressed. Also an examination of what occurs in the transition from an infant to an adult squirrel monkey, both physically and socially, a relationship is established with weight and distribution of that weight as an integral part of the life history of the organism.

THEORETICAL PERSPECTIVE

The trend in animal anatomical studies is toward the microscopic processes. Each area of expertise will study and discuss separately a small part of an organism whether it be chemical, cellular, or an individual system. They try to build the organism without knowing anything about the organism. The researchers fail to look at the "big picture". This is what the organism is as a whole, not just the small components that comprise the whole.

Those researchers who study the whole organism are making continued use of body weight both as a descriptive device and as an analytic tool (Grand 1977). They examine the anatomical structure (piece by piece) as well as relating the structure to the whole body and to the environment in which the organism lives. They look at the relationship of an organism's weight, the distribution of that weight, and how the amount and distribution of that weight changes over time.

Ted Grand has collected anatomical data on more than 150 genera of mammals through the process of full body dissection. He has examined data comparing body segments to the total body weight of individuals. Connections were then made as to how the distribution of the weight in those segments allows the organism to execute the feats that make it unique in the animal world.

His studies have included comparisons of similar but different sized organisms to individuals of the same species, at different stages of their life. His examinations are directed toward the movement capabilities of the animals and why they can move within their habitat the way they do.

The paleontologists face the challenge of reconstructing body mass from fragments of bone and teeth. They must try to reconstruct the body mass from linear measures of the bones and teeth that are found. They cannot compare the structure to another extinct organism. They can, however, look to the living organisms of today as a basis for comparison once they accept the concept that the largest tissues of the body (skin, bone, muscle, adipose stores), the dominating components of weight, vary with function and, to a degree, independently of one another (Grand 1990). Differences in the proportion of skin and muscle correlate directly with locomotor and antipredator behavior, therefore analysis of body mass must begin by interpreting functionally the largest tissues of the body (Grand 1990). This type of analysis allows for a greater understanding of the distribution of body mass and more accurate assessments can be made on the reconstruction of extinct species.

SQUIRREL MONKEY BACKGROUND

Size and weight

Neonate:

Using a colony of captive bred squirrel monkeys for a study, the analysis of 459 births showed 43 aborted or stillborn had a mean weight of 89 grams. For the 41 live-born that died within one week, the mean weight was 101 grams. The mean weight of the 375 that survived at least one week was 111 grams. The mean weight of the 237 live born males was 112 grams as compared to the females at 106 grams (Rasmussen et al. 1980). In a separate study, crown to rump measurements for males was 12 cm and females was 12 cm (Kaack and Walker and Brizzee 1979) no measurement given for tail length.

Juvenile:

In a study by Middleton and Rosal (1972), the average crown to rump length for twenty wild caught males was 25(+/).6 cm and for twenty wild-caught females was 25(+/-).4 cm. [The average tail length for males was 38(+/-).8 cm and for females 38(+/-).4 cm.] The average weight (with tail) was: 446(+/-)25 g for males and 459(+/-)17 g for females.

Adult:

The adult squirrel monkey body ranges in size from 28.3-30.9 cm (crown to rump measurement) for males and 26.3-29.0 cm for females (Rosenblum and Cooper 1968). [Tails vary in length from 32.9-46.1 cm in males and 34.6-40.0 cm in females (Rosenblum and Cooper 1968).] The adult weights (with tail) generally fall within the ranges of 700-1350 g for males and 480-750 g for females (Boinski 1989; Bowden et al. 1967; Long and Cooper 1968; Middleton and Rosal 1972; Kaack et al. 1979). These measurements are a representation of the various species and sub-species of *Saimiri.* The wide range of weight includes the males in the fatted stage during mating season and the females during the pregnancy. Weight will also vary with the availability of food (i.e. wet season vs dry season).

Locomotor importance

Survival, at all levels of development, depends on an organism's ability to move throughout its preferred habitat in order to feed, water, play, and gain social acceptance (reproduce) within its group structure. This means that an individual organism must obtain, through evolutionary changes or growth, the ability to move independently of its parents. The changes that occur throughout the life stages in relation to the distribution of weight and increased strength allow a neonate to venture from its mother's back (increased strength and musculature in the hindlimbs), to self-feeding (increased eye-hand coordination for grasping small fruits and arthropods), to moving freely among other of the same age (overall body growth and play), to developing social acceptance (reproductive ability) within the troop or in establishing a new group.

Troop demographics

The size of the group or troop is in direct relation to the condition of the habitat (Baldwin and Baldwin 1971). Areas of high vegetation and water can support a larger troop, whereas areas that have been stripped of vegetation will support smaller groups. Population density in natural environments ranges from 8 to 528 monkeys per km^2 (Baldwin 1985). The group composition will vary, but a "typical" group will contain approximately 20% infants, 32% juvenile, 29% adult female, 13% subadult males, and 6% males (Baldwin 1985).

Saimiri move through the mid-range of the forest strata but will vary levels. Groups tend to move quickly, sometimes carrying fruits in their hand or mouth with them as they move. Troops tend to spread out, not necessarily maintaining visual contact, but maintaining vocal contact. This varied movement aids in the stirring up of small insects (grasshoppers, cicadas, flies) that add to the the diet of the *Saimiri*. These small insects are taken from the ground, grabbed in flight, or plucked from the under surface of leaves and twigs. Groups will also spend time on the ground level allowing time for the juveniles to play (an activity that also occurs in trees) and also for the foraging of insects. This time is limited however and the troops will return to the safety of the trees.

Feeding and foraging

Squirrel monkeys feed primarily on soft fruits and insects (small arthropods: caterpillars, butterflies, flies, larvae, grasshoppers, cicadas, ants, and spiders) (Thorington 1968; Izawa 1975).

In primates, more so than other orders, foraging behavior involves extensive eye-hand and hand-mouth coordination (Gibson 1986). These eye-hand and hand-mouth skills are developed over time in the early to middle life stages of the squirrel monkey. Experience in the training of the musculature is necessary for the refinement of the motor skills of grasping, catching, and cleaning of food items. Social transmission of information concerning acceptable and non-acceptable foods is also a means of gaining experience in foraging (Boinski and Fragaszy 1989).

Size of the squirrel monkey largely dictates the type and size of the food it can ingest. In Peru, the average fruit diameter used by *Saimiri* is 0.6 cm and the Costa Rican *Saimiri* ingests mainly soft berry-like fruits less that 1 cm in diameter (Janson et al. 1992; Terborgh 1983). By comparison, the *Cebus albifrons* and the *Cebus apella* eat fruits with an average diameter of 1.1 cm and 1.6 cm respectfully. The *Cebus* monkey is one that shares a habitat region with the *Saimiri*. Average weight for the *Saimiri* is 0.6-1.1 kg and for *Cebus* 2-4 kg (Janson et al. 1992).

The mandible of the *Saimiri* is thinner (relative to its body size) than the *Cebus* suggesting that the *Saimiri* cannot generate as large a biting force (Bouvier 1986). The molars of the *Cebus* have a thicker enamel which allows it to chew through tough skins or coverings of fruits and nuts.

Size of a species is not the only governing factor in what the food preference will be. Other factors include the energy (and other nutrient) requirements, the time and energy allocated to foraging activities, and the physical accessibility of food items (Temerin and Wheatley and Rodman 1984). Primates that eat primarily fruit may consume large amounts of readily available carbohydrates but will have a diet deficient in proteins (Kay 1984). This protein deficiency can be made up through the consumption of insects or leaf material. An important component as to whether insect or leaves is to be eaten is based primarily on body size. Frugivores that concentrate on insects as a source for their protein tend to be small, whereas those that concentrate on leaves as a source of protein tend to be larger (Kay 1984). Dentition and the preliminary ability to prepare food for digestion is also important when connected to body size. The size and shape of the molar must be considered as it is designed to shred and crush food prior to swallowing. Primates that eat leaves or insects will tend to have a greater crushing action with their molars due to the chemical similarities between chitin, cellulose, and hemicellulose and the crushing action increases the digestibility of the materials (Kay 1984). A rough predictive guideline for molar size relating to food consumption would be: a mean M_2 length above 3.2 mm would imply a folivorous, frugivorous, or gummivorous diet and a mean M_2 length below 3.2 mm would imply a diet of insects, fruits, or gum, but not leaves (Kay 1984).

The ability to digest the eaten material is another factor governing food preference. The digestion of leaves is a long and complex process since a high percentage of their calories are locked up in structural carbohydrates (cellulose and hemicellulose) (Kay 1984). With the aid of microorganisms in the digestive tract, folivores can breakdown a small percentage of the digested material, but the process is slow and requires extensive time (12 hours or more) in the digestive tract. The digestive tract of *Saimiri* is short and therefore better adapted to digesting the insect material over the plant material (Hill 1960).

Dehydration is rapidly fatal in adults as well as infants. Water is a daily necessity for the squirrel monkey. Water accumulation is by suction from a pool of water at ground level, licking droplets of water from leaves, dipping their hands into small tree holes, or can be obtained from high water content fruits or insects (Baldwin 1985). Observations of captive squirrel monkeys with grapes showed the monkey raising its head with the mouth upwards, the fruit being held to the mouth by the hand and then squeezed until all its fluid content had been expressed (Hill 1960).

Primates encounter certain problems connected to their foraging which also are associated with their size and food preference. Problems such as: When to forage?, How to locate a food patch?, What food patch to enter?, How to acquire food items?, When to leave a food patch?, or How to move from one food patch to another? (Cant and Temerin 1984). For example: compared to the *Cebus*, the squirrel monkey is much smaller and will feed in the smaller terminal branches of most fruiting trees. This is where the most tender fruits are found. The weight of the *Cebus* will cause the branches to bend and break. To compensate however, the *Cebus* uses its prehensile tail (able to grasp structures acting as an extra functioning limb) to grasp larger branches nearby allowing it to reach out to the fruit at the ends of the branches. The squirrel monkey does not have the advantage of the prehensile tail (as an adult). The tail of the adult squirrel monkey is used as a counter-balance (by hanging the heavy tail over a branch) or in forming a tripod stance during feeding, thus allowing the smaller squirrel monkey to sit on the thinner terminal branches. Both actions with the tail will lower the center of gravity for the squirrel monkey allowing it to maintain its balance while feeding.

Predatory risk

The squirrel monkey group will tend to travel together but will break off into smaller groups or subgroups (2-8 individuals) during foraging (Baldwin 1985). They will also mix with different species groups during foraging particularly *Cebus*. The monkeys of both group keep in vocal contact and are alert to predators in the area, although the *Cebus* tend to be even more alert to problems that arise. The warning call of the *Cebus* is also interpreted by the *Saimiri* as a danger call. During the day, aerial predators seem to be the major problem for squirrel monkeys. Raptors such as Ornate Hawk-eagle, Slate-colored Hawk, or the Guianan Crested Eagle are all capable of capturing the smaller squirrel monkey (Terborgh 1983). During ground foraging a Saimiri could be attacked by a tayra or a felid, or even while sleeping at night a boa or feline attack in the tree would be possible (Terborgh 1983). Because of the overall size of the squirrel monkey, all members of the group are subject to attack. The infants and the juveniles are the easiest targets simply due to a lack of locomotor abilities to escape. The squirrel monkey manages to escape some of the attacks through its speed and agility or joining in mixed species groups.

Movement and positional behavior

Squirrel monkeys display common primate quadrupedal pronograde locomotion, in most instances of running, leaping, landing, hopping, ascending and descending on all fours (Rosenblum and Cooper 1968). When leaping they will assume an upright position using their hindlimbs for push off and their forelimbs in a swinging motion forward. This is very much like the motion that a standing broad jumper would use in attempting a jump.

Saimiri uses quadrupedal walking as its primary form of movement through its habitat (Fontaine 1990). This movement is along the top of the branch using a diagonal gait in walking and climbing. At times the squirrel monkey will employ a bipedal form of locomotion. This is primarily used when transporting an infant that is unable to cling to the dorsal surface of the mother.

When the squirrel monkey is not moving from place to place, it will sit or huddle with most of its weight on the ischium. The forelimbs also support part of the body weight. The tail is curled under the hind limbs and up over one shoulder. While sitting (resting) or sleeping, the tail is rarely left hanging below the level of the body. The adult squirrel monkey does not hang below branches. This activity is found more in the juvenile monkeys when they will suspend themselves by their hindlimbs and arm wrestle (Rosenblum and Cooper 1968).

The squirrel monkey is an endotherm, an organism capable of maintaining a stable internal body temperature. It will shiver when cold and sweat in the heat, but will avoid either action when there is another behavioral maneuver that is available to it (Adair 1985). When cold, the squirrel monkey will huddle or draw closer to other members of its group wrapping its tail around its body and tucking in its head to maintain heat, but when the temperature rises the squirrel monkey will more than likely assume a sprawl position. In this position the monkey straddles a branch, resting on the ventral surface, letting the limbs and tail dangle below (Rosenblum and Cooper 1968). As the temperature approached 90^{o} F, the percentage of sprawls to huddles rose sharply to 85-90% of postural behaviors (Dumond 1968). The sprawl is apparently related to the body heat-radiating mechanism for the squirrel monkey.

The sprawl position may also be associated with a very relaxed posture for the healthy monkey in a very nonthreatening environment. This is during times when predators would be less likely to be present. During light rains or the heat of the day, most species of predators (raptors, felines, snakes) take refuge from the weather or temperature. Both concepts (heat-radiation and nonthreatening environment) can be applied to various species outside the primate realm. Cats and dogs will tend to "spread out" or sprawl when they feel safe and secure. They will also seek out cool surfaces allowing for a maximum percentage of their body to be exposed to the surface to help in lowering their body temperature. When needing to maintain body temperature or when feeling threatened in some way, dogs and cats will "shrink" in size (huddle).

Tail function (prehensile vs non-prehensile)

The tail is an extremely important organ to the squirrel monkey when you take into consideration the length and the thickness. The tail is considered to be slightly prehensile functioning: (1) (rarely) as the third leg of a tripod to attain an erect posture: (2) as a counterweight in postural behaviors: and (3) to maintain body heat when wrapped around the body (Hill 1964; Grand 1984; Adair 1985).

At birth the neonate is able to support its entire weight with its tail (Rosenblum and Cooper 1968). For the first two and half weeks of the Bolivian species and the Colombian species life, they are able to support their body weight by their tail for up to 5 seconds (Kaack et al. 1979). However, this ability is soon diminished showing the greatest decrease in prehensile ability between 14 and 21 days old (4 seconds to less than 1) in the Bolivian species and a complete loss (unable to wrap tail around dowel) by 28 days old (Kaack et al 1979). The greatest decrease in prehensile ability in the Colombian species occurred between 21 and 28 days old with the complete loss by 28 days.

Neonates, infants, growth:

The squirrel monkey has a clear seasonal reproductive cycle and births in the wild generally coincide with the wet season, January-March (Baldwin 1985). After a gestation period of 145-155 days, birth generally occurs at night (Hopf 1967; Kaplan 1977). The majority of births happen between 2 a.m. and 6 a.m. (Manocha and Long 1977). A female generally gives birth to a single infant.

Squirrel monkeys experience rapid growth in all areas of the body (especially the head) and weight gain in the first year. In nursery-reared infants, growth was about 2.5 to 3.5 grams per day between 10 and 100 days of age. After 1.5 to 2 years of age, weight gain averaged about 0.3 grams per day in the males and 0.1 grams per day in the females (Russo et al. 1980). Mean body weight for a 1, 1.5, and 2 year old male according to Russo et al. (1980) was 600g, 680g, and 700g respectively. Mean body weight for a 1, 1.5, and 2 year old female according to Russo et al. (1980) was 570g, 600g, and 610g respectively.

The infant squirrel monkey clings to the mother's back from birth. The neonate squirrel monkey assumes this position with no help from the female. The infant maintains this position through a strong hand grasp for the fur and by looping its tail around the base of the mother's tail. The only time the infant leaves the mother's back is to nurse. This is done by sliding down the mother's side and under a forelimb to reach a nipple. The female will accommodate the infant by arching her back or shifting her forelimb ever so slightly.

The eyes of the neonate are open at birth. During the first week the infant will begin to look around at its environment and by the second week the infant will begin to reach down with its hands to grasp nearby objects. Their first independent ventures begin when they are 3 to 5 weeks old and by the time they are 8 weeks old, they are spending long periods of time off their mothers (Rosenblum and Cooper 1968). After 4 months of age the infant is rarely carried by its mother during the day but may sleep on her back until 14 months old (Rosenblum and Cooper 1968). Lactation generally ends by 6 months postpartum. The early weaning process of the squirrel monkey is directly related to its rapid growth in the first three years of its life. The young female develops more quickly than the male so she reaches reproductive status quickly.

From 6 months to 2 years of age, the young are considered to be juveniles. They begin social play as young a 2 months, but have developed play groups by the age of 6 months. Play includes running, hopping on each other, and wrestling. Play is a means of developing social status as well as muscular and skeletal development.

Life history

The squirrel monkey is considered to have a "slow" life history (as compared to the marmoset or tamarin) which incorporates the concepts of low birth rates (single birth), slow rates of development, and long lives. Females become reproductively active at the age of 2.5 to 3 years of age where the male becomes reproductively active at 4 to 5 years of age (Baldwin 1985). The young are born at a relatively constant weight in relation to the mother. The young are also born with the ability to maintain contact with the mother. The growth rate is rapid in the first year and tends to taper off over the next two years.

Even though the squirrel monkey gives birth to one offspring at a time, the percentage of infants that survive is quite high at 86% with a maximum longevity recorded at 21 years in the wild (Ross 1991).

Squirrel monkey profile

Infant stage

What is an infant? In human primates, by definition it is a live born fetus from the time of birth through the completion of one year of age. For the nonhuman primate *Saimiri boliviensis* or squirrel monkey, it is the period of time from birth to approximately 11 months of age. The infant squirrel monkey has also been defined as the period from birth to the eruption of the teeth with the third molar erupting by the 15^{th} month. The canines are the last to move into place at approximately 21.5 months (Long and Cooper 1968). This compares to the human primate with the permanent third molar erupting at approximately 18-25 years of age.

The "primary job" of the human infant is to grow and continue in its slow developmental process while being cared for by its human caretakers. Part of this "job" is learning how to survive in its new environment. The human infant learns ways of attracting the caretakers attention (crying, whining, etc.) in order to have his or her needs satisfied (hunger, change of diaper, contact). The "primary job" of the infant squirrel monkey is to grow, develop (relatively slow compared to other primates) and learn how to survive in its new environment. This is also done by learning ways to attract the caretakers attention or to learn to fend for itself as best it can (nursing technique).

The size of the cranium and the spacing of the eyes takes on evolutionary implications in the prenatal development and the visual acuity of the infant squirrel monkey. At birth, the female squirrel monkey brain is 62% of an adult brain weight, whereas the *Cebus* neonatal brain weight is less than 50% of the adult weight (Hartwig 1995). This advanced stage of development at birth allows for rapid maturation with infants achieving independence at an earlier age than most New World monkeys of similar size.

However, the increased cranium size causes some difficulties in the birth process. The possible problems are also an argument for the interorbital placement. The *Saimiri* cranium is longer and narrower than the cranium of other New World monkeys. This allows the delivery process to be completed with very little deformation of the cranium. The extreme orbital approximation is a function of the need to package the orbits of a relatively large neonate in a transverse dimension that is constrained by the size of the pelvic inlet (Hartwig 1995).

At delivery, the infant is able to grasp its mother's hair and pull itself into a ventral position on the mother's back. During the first week of the infant's life, it is not really climbing but rather holding on for life, whether awake or asleep. The infant uses it's hands (forelimbs) and feet (hindlimbs) in accomplishing this task. The female does not hold the infant to her except in a situation where the infant has been injured or is unable to hold on for itself. As long as the infant is capable of this movement on its own, the female will sit quietly and allow the infant to move from her back to her nipples for nursing. She will assist this movement only by lifting the her forelimb to allow the infant to move to a ventral-ventral nursing position.

By the second week the infant is reaching out and down to try to manipulate objects with its hands. Since the *Saimiri* is born with a mean of 8 hand/wrist ossification centers present (Watts 1990b), the muscles of the region are able to contract against a relatively solid surface. This allows for greater dexterity and manipulative movements at an early age of development. This compares to a low of 2.5 ossification centers in *Cebus apella* to a high of 23.7 in *Macaca mulatta* (Watts 1990b).

Table 1: Distribution of ossification centers in the hand/wrist area in newborn primate species

Species	Constantly present	Variably present
Macaca mulatta	distal radius, navicular, lunate, triquetral, hamate, capitate, metacarpals II, III, IV, V, proximal phalanges III, IV, middle phalanges III, IV	distal ulna, trapezium, trapezoid, os centrale, metacarpal I, proximal phalanges I, II, V, middle phalanges II, V, distal phalanges I, II, III, IV, V
Saimiri boliviensis	metacarpals II, III, IV	distal radius, distal ulna, triquetral, hamate pisiform, capitate, os centrale, trapezium, metacarpals I, IV
Pan troglodytes	distal radius, capitate, hamate	distal ulna, metacarpals II, III, IV
Cebus apella	triquetral, navicular	hamate
Cebus albifrons	triquetral	distal radius, pisiform, hamate, capitate, os centrale, trapezium

Another study by Galliari (1988) using *Saimiri boliviensis* showed the presence of ossification centers in the distal epiphysis of the femur, as well as the calcaneum and talus. Galliari's study also showed the ossification centers in the metacarpals. Other centers that appeared on a variable basis were in the proximal epiphysis of the humerus, proximal epiphysis of the tibia and some tarsals (Galliari 1988). The gestation period for the *Cebus* and *Saimiri* are very close at 155 days (avg.) while the period for *Macaca* is

170 days (avg.). This extended gestation period alone does not appear to be a reason for the greater maturity of the skeleton of the *Macaca* at birth, but may imply that skeletal ossification begins earlier or develops faster in utero for the *Macaca* than the other species listed in Table 1 (Watts 1990a).

At 3-5 weeks, the infant is beginning to become more independent of the mother. It gains a greater control of the musculature of the legs and arms allowing for greater ease in the quadruped style of locomotion. This increased ability to move about freely is enhanced by successful foraging by 7 weeks of age (Boinski and Fragaszy 1989). By 8 weeks of age the infant is spending a greater amount of time off its mother's back (Rosenblum and Cooper 1968). The first attempts to capture mobile prey happen at approximately 11 weeks of age (Boinski and Fragaszy 1989). After 4 months of age the infant is generally weaned and is rarely carried on the mother's back, but will continue to sleep on her back until 14 months of age (Rosenblum and Cooper 1968).

The monkey's highest rate of development is within the first two of years, although the squirrel monkey is considered to have a "slow" life history as defined by the concept of low birth rates (usually only one per year), slow rates of development (extended period of infancy and juvenile stages), long lives (maximum longevity recorded at 21 years (Ross 1991)). Within the first 6 months, the infant experiences very rapid growth, tripling or quadrupling the birth weight. This rapid growth tends to be a deterrent for predatory birds. Since troop movement and feeding generally occurs in the midranges of the tree, larger infants (as products of extended gestation) are less obvious prey choices for smaller birds and would stand a greater chance of surviving attacks by larger raptors like the Harpy Eagle or the Ornate Hawk-eagle (Janson and van Schaik 1993).

Juvenile stage

The definitive characteristics of juvenility concern survivability and reproductive capacity of an individual: juveniles are animals that would be likely to survive the death of their caretaker or loss of parental provisions but have not yet matured sexually (Pereira 1993). For the squirrel monkey, the juvenile period is from 11 months to 30 months in females and 36 months in males. A trait shared with human primates, the female squirrel monkey matures more quickly physically and reaches sexual maturity at an earlier age (2.5yrs) than the male (4.5-5 yrs.) of the species (Baldwin 1984).

This life stage is defined by the slower growth and development of the individual as compared to the early infant stage. The slower maturation process in the squirrel monkey over a span of 1.5-3 years allows the individual an opportunity to reach full size. In the case of the squirrel monkey, this extended maturation time decreases the risk of death in the juvenile male by avoiding the older and more experienced males of the troop during the mating season (Pereira 1993). The extended maturation time in the female may contribute to the overall success of the reproductive nature of a typical *Saimiri* troop. This is also a time of learning the social structure and overall hierarchy of the troop. Every individual must learn what his/her position or role is within the troop structure and what that position encompasses. Social learning, trial-and-error learning, and practice are all thought to play important roles in the life history of an individual.

One major feature of being a juvenile is that of using social play as a means of developing the physical fitness and social skills needed to continue to survive and to contribute to the success of the entire troop. Play is essential for the practice and learning of sex roles, dominance relationships, troop culture, integration of individuals into the troop structure, the control of aggression, and many other social behaviors (Baldwin and Baldwin 1973). Although play is not the only means of developing these attitudes, the play concept does allow for the development of more complex, varied social interaction patterns and stronger habits for engaging in frequent social exchanges (Baldwin and Baldwin 1973). Play as a means of developing physical fitness as it relates to the locomotor abilities of the monkey is directed at increasing the flexibility range of joints and the strength of the surrounding musculature. This freedom of movement has both static and dynamic components (Fontaine

1994) that should be considered.

The play activities of the juvenile *Saimiri* seem specifically adapted as a ground activity (DuMond 1968). They seek out areas where there is little underbrush and spend long period of time running, hopping on each other and wrestling (DuMond 1968) with no recognition of sexual differences. (The separation of the sexes occurs when the young females come closer to the age of sexual maturity at approximately 2.5 years of age and when the play becomes more physical and rough.) Since the skeletal and muscular systems are growing and maturing these activities would be highly precarious in the uncertain substrate of the trees. If play is engaged in in the trees, it is no higher than 10 feet and soon becomes ground play (DuMond 1968). Play is a component of the troop life that has been witnessed in the larger troops of 100 or more individuals. The larger troop size would allow for a greater number of individuals within a similar age class and size as compared to a smaller troop of 30 - 40 individuals. The larger troop size also allows for a greater number of individuals to maintain a close watch on the overall troop while on the ground and not in the safety of the trees.

Play allows the individuals the opportunity to develop four important social patterns-(1) friendly behavior, (2) controlled aggressive behavior, (3) sexual behavior, and (4) individual distances (Baldwin and Baldwin 1973).

Friendly behavior includes grooming each other, traveling and interacting as close knit groups (males and females), and sexual 'practice' by sub-adult males and females. Controlled aggressive behavior is demonstrated in chases and displays, learning to defend self, and submissive postures. Sexual behavior involves genital smelling, consorting leading to gentle mounting sequences, and learning to wait for privacy during sexual activity. Individual distances involves learning the allowable or acceptable distance from one individual to another during travel, foraging, and rest.

Play also promotes the development of dynamic and static flexibility in arboreal primates (Fontaine 1994). The term static flexibility refers to the maximal range of motion with no regard or reference to speed. Dynamic flexibility is the ability to use the range of joint movement in normal locomotor patterns at normal or increased speeds. In other words, dynamic flexibility is the freedom of motion or flexibility adapted to specific movement patterns.

The development of flexibility in play better adapts primates to the mechanical demands imposed by unstable arboreal substrata (Fontaine 1994). The reduction of quadrupedal walking in the *Saimiri* juvenile during play allowed for a greater range of movements to be explored and exploited. Specific locomotor acts in which use rates during play exceeded 200% of those for nonplay in the squirrel monkey (Fontaine's 1994 study) were: quadrupedal pronograde slide, galloping (quadrupedal locomotor mode), upside-down quadrupedalism, suspension/suspensory locomotion (locomotor use of limbs in tension), rear-first quadrupedal descent, unassisted bipedalism (climbing and bipedalism), multiple drops, single drops (leaping and dropping), hindlimb-forelimb suspensory (leaping take-off patterns), vertical (leaping and dropping landing patterns), and forelimb dominated, vertical, and hindlimb-forelimb suspensory (dropping take-off patterns).

Data from Fontaine (1994) illustrate the co-existence of multiple functions to play in the squirrel monkey. When a juvenile encountered a playmate of equal size and strength, movement patterns that allowed for dominance were employed. When a smaller, weaker, or less skilled playmate was engaged, the play was directed toward a suspensory type of play where both individuals could exercise their strengths.

The juvenile life stage allows for growth, maturation, experience, and learning to take place in a non-threatening environment. Subsequently, the result is healthy and strong adults that fit into the structure of the squirrel monkey troop.

Adult stage

The adult stage of the squirrel monkey is characterized by the onset of sexual maturity. The adult body also demonstrates muscular and skeletal differences from the younger members of the species. A difference in the distribution of the tissues of the body is evident and are directly related to the locomotion patterns of the adult (Grand 1977).

The adult squirrel monkey (infant and juvenile) is primarily an arboreal animal. With the concentration of the total body weight in the trunk, the adult is able to maintain its equalibrium on the top portion of the branches and is able to move through the trees by climbing and jumping with confidence. Unlike the juveniles who spend time on the ground playing, adults will very rarely be found out of the trees and very rarely play. The life of the adult is spent feeding/foraging, rearing young (female), and reproducing. The changes that occur within its body are directed toward ease of movement through the terminal branches of the trees, during foraging, and reproductive activities.

The adult members of the troop tend to 'socialize' with members of their own sex-age groups, meaning that adult females tend to travel, forage, and rest within close proximity to each other. However, they will interact with young females who are just entering the reproductive stage of their life. The males of the troop also tend to interact with the same sex-age class of individuals. Attempts at interaction by the juvenile or subadult males with the adult males results in aggressive behavior toward the younger members. During the mating season, the males interact with the receptive females but avoid the females that are not receptive since they give chase to the males to scare them away.

The overall size of the male is larger than the female in linear and weight measures. During the mating season, the males tend to take on a 'fatted' appearance in order to find a mate. The fatted appearance is due to an increase in the amount of fluid deposited under the skin and the muscle layers of the shoulders, back, and upper arms (Boinski 1992). The physiological mechanism for this phenomenon is the conversion of the hormone testosterone to the hormone estrogen. The more testosterone the male possesses, the more estrogen he will convert and the larger he will swell prior to the onset of the mating season (Boinski 1992). Following the mating season, the male body returns to its normal appearance.

The females, although smaller in total body weight, maintain a high level of social control within the structure of the troop. The females do not necessarily travel as a group, but will form clusters within the troop. These clusters serve as local centers of activity for other members of the troop. Even through the females do not 'socialize' with other troop members (excluding infants of less than 7 months), the other troop members are attracted to them. For instance, during the formation of rest or sleep groups, other troop members (except males) showed a preference to rest near the adult females (Baldwin 1971). The younger members of the troop also prefer to travel with the females during foraging activities. The females of the troop function to maintain the unity of the troop by forming a solid core.

Materials and Methods

Materials

The squirrel monkeys used in this study were originally used in a behavioral research project conducted by the Psychology Department at the University of Arizona. The project involved the study of natural behavior patterns among the monkeys. Interactions studied included: male/male (dominance of group), male/female (reproduction), female/female (dominant female/assisting in rearing of infants), adult/juvenile/infant (group acceptance). All parts of the study involved noninvasive techniques (Landau unpublished notes 1983). No individual monkey was subjected to any type of human induced pain or suffering.

Captive environment

The individuals in the behavioral study were originally housed in separate cages. They were eventually moved to a seminatural setting that mimicked their natural habitat which allowed for social and physical activities to take place. This new setting included ropes and artificial trees (made from pipe and plastic) necessary for this species of primate to develop physically (climbing and jumping) and socially (develop cooperation and play), along with areas where the squirrel monkey could be alone when needed by the individual (Landau unpublished notes 1983).

Sample

The sample for this project consists of five squirrel monkeys, 3 adults and 2 infants. Sex, total body weight, body length (crown to rump), and tail length are listed in Table 2.

Table 2: Specimen sex, total body weight (tbw) in grams, body length in cm (bl), and tail length in cm (tl)

specimen #	sex	tbw	bl	tl
1	adult male	937.6	29.5	37.0
2	adult female	661.0	28.5	38.0
3	subadult[a] male	545.0	27.7	40.2
4	infant male	108.1	11.5	19.1
5	infant male	102.1	10.3	15.5[b]

As stated before, all adults were feral born. They had the opportunity to grow and develop in the natural environment. Both neonates were born in captivity. Specimen 4 was born alive, but died shortly after birth. Specimen 5 was stillborn (See footnote below). A tag on the bag identified the neonate (#5) as coming from a female that died during the birth process.

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a: one who has not reached the age of sexual maturity but demonstrates adult dentition (eruption of third molar) and proper bone ossification.

b: specimen 5 - lacked the consistent moisture found in the viscera and brain tissues of the other specimens. Also, deterioration of the bony tissue inside of the long bones of the forelimb and the hindlimb was present. There was also a very strong odor present that the other specimens did not have. All information concerning this specimen will be marked with an asterisk (*).

The five specimens used represent a cross-sectional study of sex and age differences in the squirrel monkey. These individuals represent only one point in their lives in a continuum, that point being the time of their death. The information does, however, reflect the impact of their life histories on their skeletal and muscular systems.

Specimen background data

Limited individual background information, except for name, sex, feral or captive born, from the previous lab was available. All adults used were feral born and the infants were born in captivity. The ages and point of origin were not available. The specific cause of death for each individual was not available except that all deaths were due to natural causes (old age, fighting, delivery of young).

Specimen preservation

Each specimen was frozen as soon after its death as possible. The immediate freezing minimized the moisture loss in the tissues that occurs after death. As water content in body tissue changes, density of bone and other tissues will vary accordingly. In order to trace the changes that occur with a drop in moisture content in the body tissues, methods such as ash weight or calcium content of bone or dry weight of muscle would need to be used (Grand 1977).

Specimen identification

All specimens are of the Roman variety of *Saimiri boliviensis* identified through pelage patterns of the face and body (See Appendix A), total body weight, and external body measurements. These criteria are consistent with previously recorded measurements (Rosenblum and Cooper 1968; Costello et al. 1993). The following picture (Figure 1) is of two female *Saimiri boliviensis* with each carrying an infant. The female on the right is carrying her infant on her back while the one on the left shows her infant in a nursing position with its head under her forelimb.

Figure 1

Methods

Each individual was measured in the same way prior to the anatomical dissection. All types of measurements were taken which included: total body weight (tbw) and external body dimensions of length, breadth, width, height, and circumference (see Tables 3-9 for osteological markers used). Measurements were designed to delineate anatomical changes with functional and behavioral changes through the life stages of the squirrel monkey.

Total body weight was taken using a Harvard trip balance scale. Individual muscles and bones were weighed on an electronic scale (nearest tenth of a gram).

The following tools were used for linear measurements: flexible tape measure (metric), standard calipers, spreading calipers, a measurement board, and string (used as a substitute for flexible tape measure when taking circumferences of irregular or small surfaces, i.e. skull, shaft of long bone).

Linear measurements

External measurements were designed to reflect underlying osteological features. All linear measurements were taken from the right side of the body. Data were recorded in centimeters (cm). Incisions were made to assist in locating specific reference points that could not be felt through the skin. All data were recorded on data sheets created for this project.

External measurements

Body segments

Trunk

Trunk measurement was taken from the sternal notch of the manubrium to the cranial aspect of the pubis bone. A dissecting needle was inserted to maintain a constant measurement position.

Forelimb

Measurement of the forelimb was taken from the most proximal point of the humerus to the most distal end of the third digit of the hand. Individual segments of the forelimb were measured externally using osteological markers listed in Table 3. Standard calipers were used.

Table 3: osteological markers for external forelimb segment measurements

SEGMENT LENGTH	MARKER
arm	from the greater tuberosity of the humerus to the humeral-radial joint (capitulum)
forearm	from the olecranon process of the ulna to the distal head of the ulna
hand	from the proximal edge of the carpals to the distal end of the third digit

The breadth of the hand was measured at the widest point of the palm. The thumb was measured from the base of the first phalanx to the most distal end of the last phalanx.

Hindlimb

Measurement of the hindlimb was made from the greater trochanter to the distal end of the third digit of the foot. Individual segments of the leg were measured externally using osteological markers listed in Table 4. Standard calipers were used.

Table 4: osteological markers for external hindlimb measurements

SEGMENT LENGTH	MARKER
thigh	from the greater trochanter of the femur to the lateral condyle
leg	from the lateral condyle of the tibia to the lateral articular surface of the distal end of the tibia
foot	from the posterior point of the calcaneus to the distal end of the third digit. Taken on sole of foot

The breadth of the foot was taken at the widest point on the sole ofthe foot. The hallux length was measured from the base of the first phalanx to the most distal head of the last phalanx.

Tail

Measurement of the tail was taken from the first caudal vertebrae to the tip.

Head

Measurement of the head segment was done using both types of calipers. Osteological markers listed in Table 5.

Table 5: osteological markers for external head measurements

DIMENSION	MARKER
length	from the glabella to the inion
width	just above the ears, maximum bi-parietal
height	from the bregma to the goneal angle of the mandible

Face

Measurements of the face were using the spreading calipers. Osteological markers listed in Table 6.

Table 6: osteological markers for external facial measurements

DIMENSION	MARKER
length	from the nasion to the gnathion (point of the mandible)
width	bizygomatic

Circumference measurements

Circumferences of the body segments were taken at the following points using the flexible tape measure or string substitute. Osteological markers for circumference are listed in Table 7.

Table 7: osteological markers for external circumference measurement

BODY SEGMENT	MARKER
head	the point just superior to the eye orbits
thorax	at the inferior end of the manubrium
arm	midpoint of the humerus
forearm	midpoint of the ulna and radius
thigh	midpoint of the femur
leg	midpoint of the tibia and fibula
tail	1 inch caudally from the base (adult) and 1/4 inch caudally from the base (infant)

Internal measurements

Bone

Measurement of the bones (in centimeters) included maximum length, diaphyseal length, and in the case of the heavier weight bearing bones (humerus and femur) the diameter was taken at midshaft. The measurements were taken using standard measurement techniques listed in Table 8.

Table 8: osteological markers for bone

BONE/BONE SEGMENT	OSTEO MARKER
skull:	
length	glabella to inion
base	basion to inion
face width	bizygomatic
clavicle:	
maximum length	sternal end to acromial end
diaphyseal length	from epiphyseal line to epiphyseal line
scapula morphological length	glenoid fossa to root of spine
humerus:	
maximum length	greater tuberosity to distal trochlea
diaphyseal length	posterior lateral edge distal point of greater tubersosity to proximal extent of later posterior trochlea
midshaft of diaphyseal length	anterior to posterior
midshaft of diaphyseal length	medial to lateral
ulna:	
maximum length	olecranon process to styloid process, midpoint trochlea to distal head
diaphyseal length	posterior olecranon process to epiphyseal line above styloid process

Table 8 (cont.)

radius:	
maximum length	proximal head to styloid process, head to radial fossa
diaphyseal length	posterior surface just below proximal head to epiphyseal line just above dorsal tuberosity
femur:	
maximum length	femur head to distal medial condyle, greater trochanter to distal epicondyle
diaphyseal length	posterior epiphyseal line below proximal head to proximal medial articular surface
midshaft diameter	midpoint of diaphyseal length anterior to posterior
tibia:	
maximum length	from proximal articular surface to medial malleolus, proximal tibial facet to distal articular surface
diaphyseal length	posterior midpoint below proximal articular surface to midpoint above distal articular surface
os coxa:	
maximum length	most proximal point of acetabulum to proximal extent of ilium
ilium breadth	widest point of ilium

Dentition

The morphology of the second molar (M_2) is a standard for determining diet and is directly related to body size (Kay 1984). The first molar is variable in size and the third molar is frequently missing in *Saimiri* (Hill 1960). Measurements of the teeth included the length and breadth of only the second molar (maxillary and mandibular). The standard calipers were used and Table 9 lists method of measurement.

Table 9: measurement standards for second molar

DIMENSION	DIRECTION
maximum length	mesial / distal
breadth	buccal / lingual

Anatomical dissection

Importance of gross dissection

Comparative vertebrate anatomy (CVA) through gross dissection is being attacked from a variety of agencies (local and federal) wanting this form of research and study to be replaced with computer simulations (Grand 1995). Anatomical investigations are moving toward a study of the molecular composition of the individual. This "molecular reductionism" (Grand 1995) focuses on the biochemical aspect of the individual with little or no regard for the whole organism.

Research focusing on the reasons <u>why</u> individuals can move the way they do and <u>why</u> that movement is important to the individual throughout its life stages should be through the measurement and analysis of its bones and muscles. Gross dissection and the use of video technology are two primary methods in analyzing the weight, length, and function of the bones and muscles in the body of the individual organism. In this way, a direct relationship between the structure and the function can be established.

In this project, one side of the dissected body was used to measure limb segment weights, lengths, and circumferences. The other side was used for individual muscle measurements. Specific dissection techniques for the squirrel monkey are listed in Appendix F.

Weights

Muscles

Muscles were identified by the the origin and insertion points of the tendons and removed as a whole unit. Decisions concerning allocation of muscle to particular body segments were based on muscle-bone/form-function relationships. Muscles were weighed immediately upon removal from the bone in order to minimize moisture loss[c].

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c: The variation in moisture distribution upon the death and subsequent freezing (body position, i.e. which side the animal was placed on) is masked by averaging weight values for adults and neonates in this sample.

Bone

All extraneous tissues (veins, fat, etc.) were removed from the bone and weighed. Bones were weighed wet. The skull was weighed, once with the brain tissue intact and once after the brain tissue had been removed.

Brain

The difference in weight between the skull with brain tissue and the skull without the brain tissue represents the brain weight.

Cranial capacity

The cranial capacity was determined by filling the cranial cavity with mustard seed (making sure that all the areas were filled by using a small spatula to move the seed inside the skull) level with the opening of the foramen magnum. No plugs were necessary since there were no external openings large enough to allow the mustard seed to leak out other than the foramen magnum. Once completed, the mustard seed was poured into a graduated cylinder for the volume measurement.

DATA ANALYSIS

Primary form of analysis is through comparison of percentage of mean body segment weights to mean total body weight (tbw) of the sample for adults versus infants. This demonstrates the proportional change in skeletal and muscular systems. Comparison of volume of muscle within a segment and the length of the segment demonstrates the potential for muscular action on the bony structure (muscle contraction for movement versus contraction for sustained grasp).

Table 10 lists the formulas used in analyzing the percent difference between: internal and external bone measurement; forelimb to hindlimb; forelimb; hindlimb. A comparison of muscle volume to bone length is made to determine type of muscle contraction possible. All comparisons are between the adult and neonate.

Table 10: Body proportion measurements

#1	Difference between internal and external bone measurements: ([mean ext. segment l. - mean int. bone l.]/mean ext. segment l)x 100	
#2	Intermembral Index:	[humerus + radius / femur + tibia] x 100
#3	Brachial Index:	[radius/humerus] x 100
#4	Crural Index:	[tibia/femur] x 100
#5	Ratios: Bone length, weight, muscle weight, total body weight	adult measure/infant measure

Data analyzed delineates the changes in body weight and distribution of that weight to known movement capabilities of the squirrel monkey through its life stages. This allows for an understanding of the relationship of physical development to the preferred habitat of the individual species.

RESULTS

The following results outline the weight distribution, the internal bone lengths to external segment measurement, and the ratio differences of bone length, bone weight, and muscle weight between the infant and adult specimens. This comparison allows for an evaluation of the segments and the tissues required for changing locomotor patterns throughout the life stages of the squirrel monkey. Discussion and interpretation of each sub-heading is found in the next section. Complete listing of raw data can be found in Appendix D.

Whole body

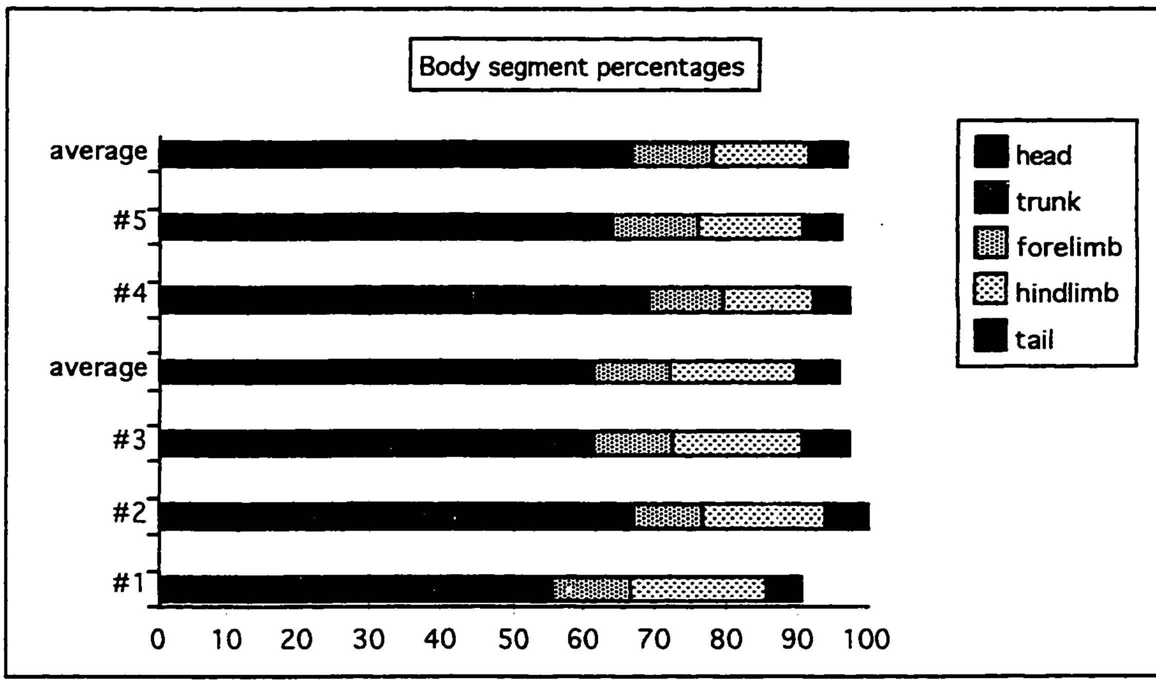
Segment percentages

The percentage of total body weight contained in the individual body segments is given in Table 11. The bar graph representation of the individual segments and the average comparisons are found in Figure 2.

Table 11: Body segment percentage based on TBW (recorded in grams)

specimen	head	trunk	forelimb	hindlimb	tail
#1	10.5	45.0	11.2	18.6	5.0
#2	10.2	56.7	9.8	17.0	6.6
#3	14.2	47.1	11.2	18.0	6.8
avg.	**11.6**	**49.6**	**10.7**	**17.9**	**6.1**
#4	29.0	40.0	10.2	12.6	5.6
#5*	24.0*	40.0*	12.0*	14.4*	5.9*
avg.	**26.5**	**40.0**	**11.1**	**13.5**	**5.75**

Figure 2



d: Total of body segments do not total 100% of total body weight. Missing percentage is equivalent to 'other' category for fluids, fats, mesentery tissue or measurement error not accounted for during dissection procedure. Percentages are based on average weights and measurements and rounded to the nearest whole number.

Tables 12 and 13 outline a breakdown of each segment in regard to bone, muscle, skin and 'other' as they relate to total body weight.

Table 12: Infant bone, muscle, skin, other segment analysis of 105g TBW (average weights of sample)

Segment	Bone	Muscle	Skin	Other*
Head	8.1g / 7.7%	0.7g / 0.7%	5.1g / 4.9%	26.3g / 25% total
Trunk	8.6 / 8.2	9.9 / 9.4	11.2 / 10.7	
Forelimb	3.6 / 3.4	4.0 / 3.8	3.1 / 3.0	
Hindlimb	4.1 / 3.9	5.1 / 4.9	3.7 / 3.5	
Tail	1.5 / 1.4	2.2 / 2.1	2.2 / 2.1	

* category includes weights of organs, brain, tongue, eyes, mesentery tissue, fat, etc.

Table 13: Adult bone, muscle, skin, other segment analysis of 714.5g TBW (average weights of sample)

Segment	Bone	Muscle	Skin	Other*
Head	21g / 2.9%	9.3g / 1.3%	15.3g / 2.1%	176.4g/ 24.7% total
Trunk	46.2 / 6.5	141.7 / 19.8	49.4 / 6.9	
Forelimb	12.8 / 1.8	42.7 / 6.0	20.4 / 2.9	
Hindlimb	21.9 / 3.1	79.4 / 11.6	25.0 / 3.5	
Tail	10.6 / 1.5	22.0 / 3.1	9.9 / 1.4	

* category includes weight of organs, brain, tongue, eyes, mesentery tissue, fat, etc.

Head

The head of the infant makes up 27% of the total body weight as shown in Figure 2. This large cranium houses a very large brain at 40% segment weight. The volume of the eye orbits is 1.3% of the segment weight (relatively small when compared to the adult volume stated below) and are spaced in close proximity to each other. This compares to the adult head that encompasses only 12% of the total body weight with a brain weight of 31% segment weight. The volume of the eye orbits of the adult make up approximately 3.6% of the segment weight. Refer to Tables 12 and 13 for bone, muscle, skin and 'other' percentage to TBW.

Trunk

The main body or trunk of the infant squirrel monkey is is 40% of the total body weight. The adult trunk comprises 50% of the total body weight. Refer to Tables 12 and 13 for bone, muscle, skin and 'other' percentage to TBW.

Forelimb

The percentage of total body weight in both, the adult and the infant is recorded at 11%. The variation is in the distribution of weight within the segment as shown in Figures 3 and 4. The infant upper arm comprises 33%, forearm 36% and hand 22% of the forelimb segment weight. The adult forelimb segment weight is distributed as follows: upper arm 49%, forearm 37% and hand 11.5%. Refer to Tables 12 and 13 for bone, muscle, skin and 'other' percentage to TBW.

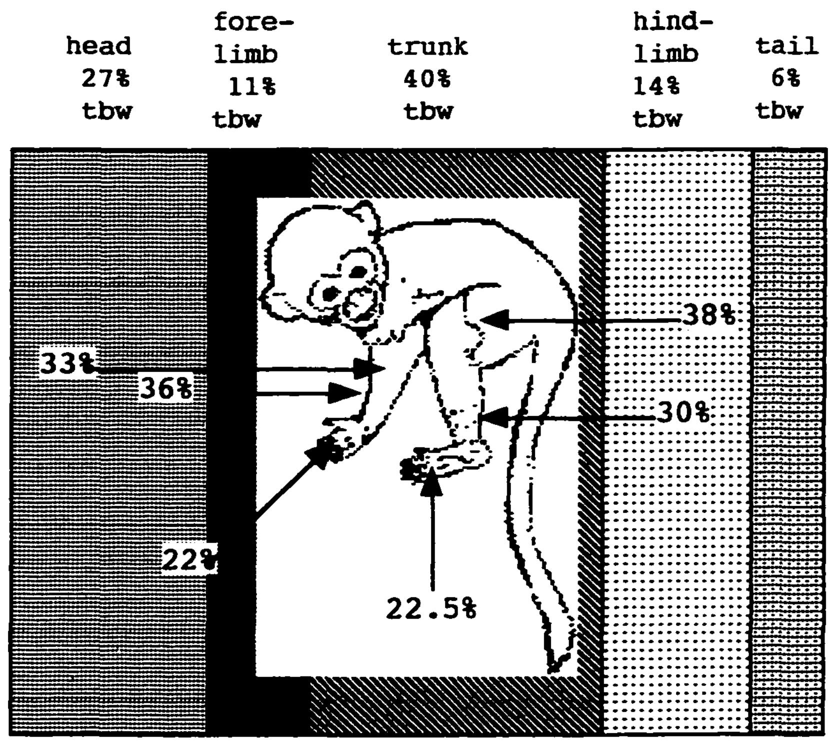
Hindlimb

The hindlimb of the infant squirrel monkey contains 13.5% of the total body weight of the individual as compared to 17.9% TBW in the adult. The hindlimb segment weight distribution in the infant is: thigh 38%, leg 30% and foot 22.5% and the segment weight distribution in the adult is: thigh 60%, leg 26%, and foot 12.5%. Figures 3 and 4 show the distribution of weight within the segment. Refer to Tables 12 and 13 for bone, muscle, skin and 'other' percentage to TBW.

Tail

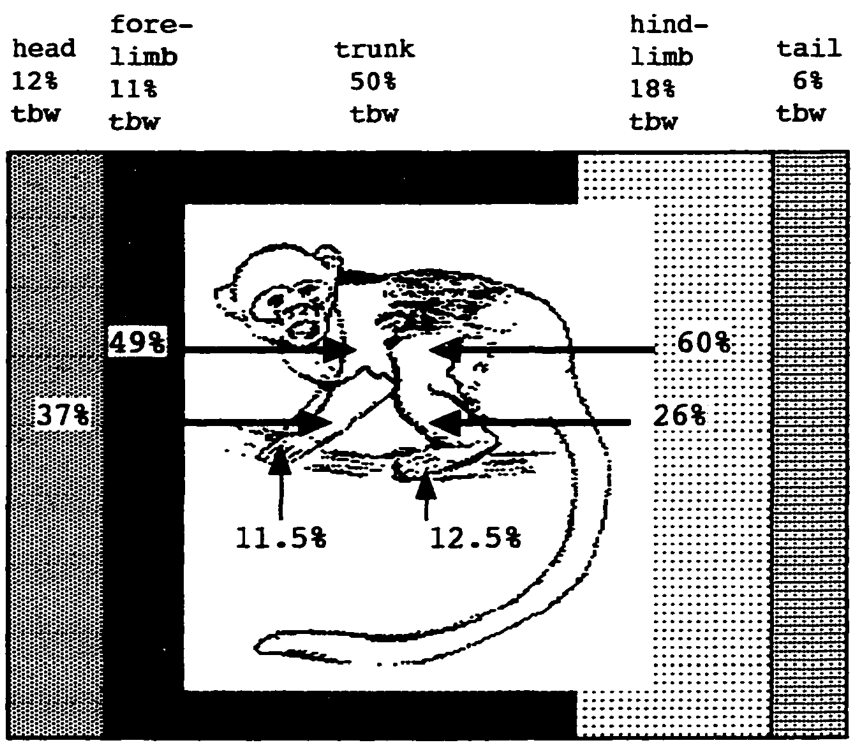
The tail segment of the infant comprises 5.75% TBW and the adult 6.1% TBW. When rounded as shown in Figures 3 and 4 the percentage is equal at 6.0%. Refer to Tables 12 and 13 for bone, muscle, skin and 'other' percentage to TBW.

Figure 3 Segment analysis squirrel monkey infant



Percentages within the diagram represent the
percentage of the limb weight, not of TBW

Figure 4 Segment analysis squirrel monkey adult



Percentages within the diagram represent the percentage of the limb weight, not of TBW

Limb measurements

Internal/external comparison

The percent difference in the external measurement of a segment and the internal bone length of the segment can be found by using formula #1 listed in Table 10.

Osteological markers (Tables 3 and 4) were used for reference points on the forelimb and hindlimb segments. Internal bones were measured using the diaphyseal lengths. This allows for a comparison of the adult to the infants in terms of bone and segment lengths.

Table 14: External/internal percent difference segment analysis

Segment	Adult	Infant
Arm/humerus	7.0%	20.0%
Forearm/radius	9.0%	27.0%
Thigh/femur	6.0%	24.0%
Leg/tibia	16.0%	29.0%

Intermembral index

The index for the adult squirrel monkey is 79% as compared to 92% in the infant. Formula #2 from Table 10 was used to determine the index.

Brachial index

The index for the adult squirrel monkey is 96.8% as compared to 96.4% in the infant. Formula #3 from Table 10 was used to determine the index.

Crural index

The index for the adult squirrel monkey is 97.5% as compared to the infant at 101.7%. Formula #4 from Table 10 was used to determine the index.

Ratio comparisons

Tables 15 - 21 represent the ratio comparisons in the length of the bones of the forelimb and the hindlimb, the weights of the bones of the forelimb and the hindlimb, and the weights of the muscles of the forelimb and the hindlimb. Ratios are stated using the infant as the constant for measurement (1cm).

Table 15: Forelimb bone length Ratio: Adult to infant (avg. of sample)

Bone(s)	Adult Bone length(cm)	Infant Bone length(cm)	Bone length ratio
Humerus	6.3	2.8	2.3:1
Radius	6.1	2.7	2.3:1
Hand	4.9	2.6	1.9:1
total	**17.3cm**	**8.1cm**	**2.1:1**

Table 16: Hindlimb bone length Ratio: Adult to infant (avg. of sample)

Bone(s)	Adult Bone length(cm)	Infant Bone length(cm)	Bone length ratio
Femur	8.0	3.0	2.7:1
Tibia	7.8	3.0	2.6:1
Foot	7.9	4.5	1.8:1
total	**23.7cm**	**10.5cm**	**2.3:1**

Table 17: Forelimb bone weight Ratio: Adult to infant (avg. of sample)

Bone(s)	Adult bone weight(g)	Infant bone weight(g)	Bone weight ratio
Humerus	1.9	0.6	3.2:1
Radius/ Ulna	2.0	0.6	3.3:1
Carpals/ Metacarpals/ Phalanges	1.8	0.7	2.6:1
total	**5.7g**	**1.9 g**	**3:1**

**Table 18: Hindlimb bone weight
Ratio: Adult to infant
(avg. of sample)**

Bone(s)	Adult bone weight(g)	Infant bone weight(g)	Bone weight ratio
Femur	4.0	0.7	5.7:1
Tibia/ Fibula	3.5	0.5	7.0:1
Tarsals/ Metatarsals/ Phalanges	3.3	0.8	4.1:1
total	**10.8 g**	**2.0 g**	**5.4:1**

**Table 19: Forelimb muscle weight
Ratio: Adult to infant
(avg. of sample)**

Segment	Adult muscle weight(g)	Infant muscle weight(g)	Muscle weight ratio
Arm	11.6	0.7	16.6:1
Forearm	9.4	1.2	7.8:1
Hand	0.4	0.2	2.0:1
total	**21.4 g**	**2.1 g**	**10.2:1**

Table 20: Hindlimb muscle weight Ratio: Adult to infant (avg. of sample)

Segment	Adult muscle weight(g)	Infant muscle weight(g)	Muscle weight ratio
Thigh	29.0	1.5	19.3:1
Leg	9.7	1.0	9.7:1
Foot	1.0	0.2	5.0:1
total	39.7 g	2.7 g	14.7:1

Table 21: Total body weight ratio Adult to infant (avg. of sample)

Adult body weight(g)	Infant body weight(g)	Total body weight ratio
714.5	105.0	6.8:1

Dentition

The average length of the second maxillary molar (M^2)in the adult specimen was 0.2cm. The average breadth was 0.33cm. The average length of second mandibular molar (M_2) was 0.25cm with an average breadth measurement of 0.25cm.

There are no data available on the teeth from the infants of the sample. Their deaths occurred prior to the eruption of any teeth.

Discussion

The primary question to be answered in this project has been how the skeletal and muscular development of the squirrel monkey affects its locomotor patterns from the infant stage to the adult. The following interpretations will demonstrate the changes that occur through the life of the individual. Although the sample size is small, the comparisons of the infant skeletal/muscular systems to the adult skeletal/muscular systems is enticing in nature.

Whole body

Each individual is a compilation of bone, muscle, skin and other tissues that make up the whole organism. A comparison of tissue percentages to the total body weight of an organism, comparisons of tissue distribution and internal to external measurements allows for a picture of the individual and the movements that individual is capable of developing. Concentrations of tissues in certain areas of the body lend an understanding to the types of movements or abilities generated by the individual segments.

Tables 12 and 13 demonstrate the breakdown in individual tissues for the sample. As with the body segments, the infant squirrel monkey demonstrates equal distribution in regard to the different types of tissue that make up the body. Bone comprises 24.6% tbw; skin 24.2% tbw; muscle 20.9% tbw; and other tissues 25% tbw. Muscle tissue is measured as the lowest percentage of TBW which would account for the limited movement capabilities of the individual. Complex movements such as climbing or running along a branch require more muscle and greater control than the infant is capable of with the limited muscle development. As the infant grows and develops into a juvenile, the muscle weight of the body increases through growth and use. This growth of muscle is not uniform in its development. Rather, it varies according to the individual's genetic background, overall nutrition, and exercise.

The distribution of tissues in the adult differs greatly from the infant. Where as the infant demonstrates an almost even tissue distribution, the distribution of tissue in the adult shows the highest percentage in muscle at 41.8% tbw; skin 16.8% tbw; bone 15.8% tbw; and other tissues 24.7%tbw. Where the infant muscle was the lowest percentage of total body weight, the muscle is the highest concentration of tissue in the adult (limited movement capabilities to complex movement capabilities). The bone weight shifts from second in the infant to third in the adult. As the body size increases, the skeleton becomes lighter to facilitate movement. The squirrel monkey lives and moves through the mid-range of the canopy and uses terminal branches to move from tree to tree. If the monkey possessed a heavy skeleton and a heavy musculature increased weight of the monkey could possibly alter its preferred habitat. This monkey might then choose to live in the lower heavier branches or possibly develop as a terrestrial monkey.

The tail of the infant contains 10% of the total muscle weight. It also contains 2.2g or 8.7% of the total skin weight. The tail is used as an anchor point while wrapped around the base of the mother's tail when the infant is on the back of the female. The muscle present in the tail is sufficient to support the weight of the light infant in the first few weeks after birth. As the infant grows and its total body weight increases, the muscle of the tail is insufficient in supporting its weight. The percentage of muscle in the tail decreases to 7.5% of the muscle weight in the adult.

The head of the infant makes up 27% of the total body weight. The muscle of the head comprises on 3.1% of the total muscle weight. The brain, eyes, and tongue make up 41.2% of the segment weight with the bone comprising 31.3%. The skin makes up 20.2% of the segment weight. The brain alone accounts for 37.7% of the segment weight. This large brain is necessary for the early and quick learning that takes place with the infant squirrel monkey.

The trunk of the infant contains the highest amount of muscle at 9.9g or 45.2% of the total muscle weight. This segment of the body maintains the highest amount of muscle weight throughout the life stages of the squirrel monkey. This is because it is the largest segment, but it is also the anchor to which all parts of the body are attached. The trunk is the center of all body functions and the bodies center of gravity is located in this segment.

The tail of the infant has a bone concentration of 1.5g or 5.8% of the total bone weight as compared to 10.6g or 9.4% of the total bone weight in the adult. A comparison of muscle shows the infant with 2.2g or 10.0% of the total muscle weight and the adult at 22.0g or 7.5% of the total muscle weight.

The percentage of total body weight, the percentage of muscle weight, and the percentage of bone weight in the infant extremities show a concentration in the distal portion of the limbs. This combination of muscle and bone weights in the infant extremities provides a strong structure away from the center of the body. The amount of bone and muscle weight in the extremities, the head, and the tail is vital in maintaining the body's equalibrium since the infant spends the first couple of weeks of its life on its mother's back, and later as a juvenile shifting to an exploratory mode of locomotion (crawling, climbing), The key form of attachment and safety for the infant is through the gripping action of the hands, feet, and tail. As the infant matures, the concentration of bone and muscle weight moves toward the central portion of the body. This allows for quicker and more steady forms of movement for the adult in the forest substrate.

The adult body is heavy in muscle tissue at 41.8% TBW. A typical adult primate muscle weight is approximately 40% of TBW (Grand 1976). Everything the adult does and is depends on its ability to move (foraging, mating, escaping), thus the high muscle content and strong skeletal support. An animal who has lost its movement capabilities is a prime target for predators.

Within the sample, I found it interesting that the female adult specimen had a higher percentage of bone than the two adult male specimens. I account for this as a means of preparing for the reproductive phase of her life. The mass of her skeleton is the direct support in the carrying of a fetus through the extended gestation period. Following birth, the female carries the infant on her back up to 14 months of the infant's life. She is also producing milk for the infant which causes a strain (calcium drain) on the skeletal structure of most primates. The added bone mass plus her musculature allows for this process to occur without causing undue strain or injury to the female.

Segment percentages

Head

The infant squirrel monkey's head is very large in relation to the rest of its body. The head, making up 27% of its TBW accommodates a large brain (average 10.7g). The brain equals 10.2% of the average TBW. The eyes of the infant make up 0.7% of the TBW allowing for an increased level of observation and awareness at birth. The larger brain and more complete neurological connections that a neonate possesses at birth, the more it is capable of tending to its needs without the major assistance of the female. The size of the cranium and the spacing of the eyes take on evolutionary implications in the prenatal development and the visual acuity of the infant squirrel monkey. This advanced stage of development at birth allows for rapid maturation with infants achieving independence at an earlier age than most New World monkeys of similar size.

The adult head encompasses 12% of its TBW. This houses a brain with an average size of 25.7g or 3.6% TBW. The adult continues to learn throughout its life. The majority of what it needs to survive is learned through observation and experience and takes place in the first few years of its life.

Trunk

The trunk of the squirrel monkey is the largest section of the whole body at 40% TBW in the infant and 50% TBW in the adult. The trunk houses the vital systems required for growth and reproduction of the individuals. The trunk is vital for maintaining fluid content and body heat. All processes that take place within the trunk radiate to the appendicular portions of the body.

Forelimb/hindlimb

The distribution of the muscle of the body is a prime consideration when discussing movement capabilities whether it be in the infant or the adult squirrel monkey. The percentage of total body weight for the adult and infant forelimb are the same at 11.0%. The TBW percentage in the hindlimb is 14.0% for the infant and 18% for the adult. The difference in the distribution of the weight and the function of the muscle and bone is the key factor in determining the type of locomotor patterns that can be achieved.

The infant forelimb and the hindlimb combined contain 9.1g or 41.6% of the total muscle weight. The distribution of this limb muscle shows the forearm with the greatest amount of muscle at 57.5% of the segment muscle weight and the thigh at 56.9% of the segment muscle weight. For the infant, the high percentage of muscle in the forearm combined with the 7.5% segment muscle weight in the hand allows for an increase in the ability to grip with the fingers of its hand. Not only does the infant demonstrate a strong gripping ability, but it is able to sustain the grip for extended periods of time, even while sleeping. The high percentage of muscle in the thigh will develop into more of a propulsion type muscle as the infant grows. However, during the infant stage the thigh at 56.9% of segment muscle weight combined with 5.9% segment muscle weight in the foot and the 39.2% of the segment muscle weight in the leg works together with the forelimb for a consistent or equal gripping action between the forelimb and the hindlimb.

A major characteristic of the infant is its ability to cling or grasp the hair of its mother. This is an innate life saving characteristic as the female is not always the best at maintaining physical contact. The infant must literally 'hold on for life' for extended periods of time whether awake or sleeping and whether the female is at rest or moving. The grasping ability which allows the infant to cling is dependent on the percentage of muscle in the forelimb and hindlimb of the individual. The percentage of muscle and the ossification centers present in the wrist and hand (Table 1) of the infant offer an early base for muscle contraction to occur.

When muscles are held in a contracted phase for extended periods of time, fatigue will naturally set in causing a gradual loss of contractibility within the fibers of the muscle. When the muscles of the forelimb and hindlimb contract, individual motor units within the muscle will contract at different times. This allows for a steady increase in tension production. The high percentage of muscle in the limbs allows for a greater concentration of motor units to be present. When contraction of the muscle occurs, only a fraction of the motor units respond to the stimulation. As the muscle fibers within the motor units become fatigued, other units are stimulated. This stimulation/relaxation of motor units allows for a constant grip to be maintained. This type of muscle contraction is referred to as "treppe contraction" (Martini 1995).

The distribution of the muscle weight in the adult shows the highest percentage in the trunk at 48% of the total muscle weight. The combined muscle weight of the forelimb and the hindlimb in the adult is 122.1g or 41.4% of the total muscle weight. The forelimb contains 42.7g or 14.5% of the total muscle weight with 39.8% of the segment muscle weight found in the upper arm, 31.3% in the forearm and 28.9% in the hand. The hindlimb contains 79.4g or 26.9% of the total muscle weight. The distribution of the muscle is: thigh 36.5%; leg 33.3%; and foot 29.7% of the segment muscle weight.

The distribution of bone in the body of the squirrel monkey needs to be taken into consideration along with the musculature. The forelimb of the infant contains 3.6g or 13.9% of the total bone weight. The distribution of the forelimb segment bone weight is: humerus 1.1g or 30.6%; forearm 1.1g or 30.6%; and hand/wrist 1.4g or 38.8%. The hindlimb makes up 4.1g or 15.8% of the total bone weight. The distribution of the hindlimb segment bone weight is: femur 1.4g or 34.1%; leg 1.1g or 26.8%; and foot/ankle 1.6 or 39.0%.

The bones of the hindlimb and forelimb of the adult comprise 34.7g or 30.8% of the total bone weight. The forelimb segment of bone is 12.8g or 11.4% of the segment bone weight. The distribution of bone weight in the forelimb is as follows: humerus 5.1g or 39.8%; forearm 4.0g or 31.3%; and hand 3.7g or 28.7%. The hindlimb segment of bone is 21.9g or 19.5% of the total bone weight. The distribution of the segment bone weight in hindlimb is: femur 8.0g or 36.5%; leg 7.3g or 33.3%; and foot 6.5g or 29.7%.

The combination of the highest concentration of muscle weight and bone weight in the upper portion of the limbs supports the movement pattern of reaching and pulling the body with the forelimb, and a pattern of pushing off with the hindlimb. The adult climbs through the branches, jumps from branch to branch, and runs along small branches. With the concentration of muscle and bone tissue toward the central portion of the body, the adult is able to maintain its equalibrium while moving quickly. Survival is dependent on the ability to move throughout the preferred habitat without falling or remaining exposed for extended periods of time in the trees.

The bones of the appendicular skeleton with the joints as connectors, provide a series of levers the muscles work with in order to create movements. The overall length of the lever in relation to the amount of force that can be applied determines whether the movement is dynamic or static (propulsion or gripping strength). The final comparison of the bones and muscle come in a direct ratio of the two between the adult and the infant (Tables 15-20). In regard to length of the bones there is a 2.1:1 ratio (adult:infant) in the forelimb and a 2.3:1 ratio in the hindlimb. The ratio of muscle weight is 10.2:1 for forelimb and 14.7:1 in the hindlimb. With the average of the adult forelimb being twice as long as the infant but containing ten times as much muscle, the conclusion would be that the infant forelimb has a very high amount of muscle for its length. This would give the infant a short lever with a strong force that could be applied. But since the lever is so short, the force is not applied to dynamic movement but rather to its gripping ability. The same principle holds for the hindlimb except that the potential for the development of propulsion type muscle is greater with the higher concentration of muscle.

If the reverse interpretation is used the adult forelimb contains 10 times as much muscle over twice as much bone offers a longer lever for the force to be applied to. The longer lever would be associated with gross motor skills such as climbing or running, where the limb would need to be stretched out and pulled in as compared to fine motor skills as gripping or food manipulation. The same principle, when applied to the hindlimb with almost 15 times more muscle to just over twice as much bone, dictates movement with a greater force than in the forelimb. The type of movement generated by this intense force would be propulsion used in jumping or springing from branch to branch.

When comparing the amount of force on the bone and joints, the implication is that the shorter limb and high amount of force allows for a greater degree of sustained muscle contraction. This would account for the ability of the infant to remain in direct physical contact with the female for extended periods of time with no assistance through a sustained gripping action of the hands, feet and tail. The muscle to bone comparison in the adult would dictate mobility over sustained contraction and would account for the ability to pull or climb with the forelimb and propel (jump) with the hindlimb.

Tail

Figures 3 and 4 show the tail of the adult and infant at the same percentage of total body weight. Table 11 shows a slight difference prior to rounding of the numbers. The tail of the infant at 6% TBW can be and is usually wrapped around the base of the mothers tail while the infant is on her back. This is one additional anchor to prevent the infant from slipping off the mother's back. The total muscle weight found in the tail of the infant is 2.2g or 10.0% of the total muscle weight. This is combined with 1.5g or 5.8% of the total bone weight. The high concentration of motor units within the tail muscle allows for a more constant form of muscle contraction (more motor units cycling through the contraction phase) used for an extended period of time in grasping an object or supporting weight.

As the squirrel monkey grows and the concentration of muscle tissue changes, the tail is affected. The adult has 22.0g of muscle in the tail or 7.5% of the total muscle weight. This decrease in the concentration of motor units causes a decrease in the grasping ability of the tail. But the percentage of bone in the tail of the adult increases to 10.6g or 9.4% of the total bone weight. This combination of tissue development allows the tail to become a support to be leaned on, used as a counter-balance, or wrapped around the body for warmth.

Internal/external measurements

Developmental differences or stages of the skeleton are a means of identifying adults, juveniles and infants. The skeleton as a whole begins as cartilage and through time most of the structure ossifies into a calcium based structure referred to as bone. The skeleton of the infant primate contains high amounts of cartilage as the ossification process is in the beginning stages. As stated before, the hand/wrist area of the infant squirrel monkey contains 8 ossified segments, but the long bones of the infant contain large amounts of cartilage in the epiphyseal regions of the bone. As the infant matures, this region hardens into a bony structure. The degree of cartilage remaining is a determinant for the age of the skeleton.

Diaphyseal measurements of the bones were used for the internal length of the long bones. This measurement takes into account the area of the bone that has ossified. This length is shorter in the infant stage of bone development than in the adult.

External measurements are taken from the osteological markers of the bone. These markers are present in the infant and adult stages. The markers are located in the epiphyseal region of the bone. Even though this region has not hardened in the infant, the marker is still present. The differences in the degree of bone development in the epiphyseal region would account for the high percentage differences in the internal/external measurements of the infant.

The differences between internal bone measurements and external segment measurements of the adult are consistently lower than those of the infant. The forearm/radius and leg/tibia showed a higher percentage difference in measurement.

Indices comparison

Intermembral index

The comparison of the forelimb to the hindlimb shows the adult with a forelimb that is 79% of the total length of the hindlimb. This is 1% less than the reported index by Fleagle (1988) at 80% for the squirrel monkey. This accommodates the movement pattern of propulsion with the longer hindlimb. The forelimb is used primarily for climbing (pulling) and feeding. The shorter forelimb would also account for the slight horizontal positioning of the trunk while sitting.

The infant shows a forelimb index of 92%. The forelimb and hindlimb are very close to equal length. The movement of the infant in the early stages of its life is one of balance rather than movement from place to place. The almost equal length of the limbs allows for greater control while clinging the back of the mother.

Brachial index

The brachial index for the adult and the infant shows a humerus that is longer than the radius. For the adult, it is only 3.2% longer which demonstrates a forelimb designed for reaching and pulling. Two very similar levers working together with the attached musculature offers a very smooth and even working machine capable of moving the mass of the total body.

The infant also demonstrates an evenly diststributed forelimb with a 3.4% difference. The forelimb is wrapped around the shoulders of the mother. The increased musculature in the forearm and hand allows for the gripping that is necessary to maintain its equalibrium.

Crural index

The crural index for the adult squirrel monkey shows a femur that is slightly longer that the tibia in the hindlimb. The femur holds the bulk of the muscle found in the hindlimb and offers a platform for propulsion (running, jumping).

The infant shows a slightly shorter femur. The tibia is 1.7% longer than the femur. The combination of the longer leg segment and the musculature allows for a gripping action over propulsion in the hindlimb. The infant is more concerned with stability over leaping and running.

Dentition

The teeth of the adult squirrel monkeys are consistent with the size of molars referred to on page 12 (Kay 1984). The size is consistent with an animal that has a diet of fruits, flowers, and arthropods.

No interpretation can be offered for the teeth of the infants. As with all the life stages, certain processes occur during different phases of each stage. Neither of the infants had reached the phase in their life cycle where the teeth had erupted through the gums.

Summary

The character of an infant squirrel monkey is one of survival. Being born at an advanced stage of awareness (relative to other primates) with the ability to adjust to its surroundings with little or no help from the mother is contributed to the size of the cranium and the level of brain development. The structure of the body allows the infant the ability to maintain contact with the mother that is necessary early in its life.

As the infant begins to mature, more strength is required to move the individual through its habitat. This strength develops in several ways: (1) The infant will begin to increase in overall body weight which demonstrates an increase in the percentage of muscle mass within the individual, (2) Exercise through movement away from its mother and eventually play will facilitate the development of muscle mass in the body.

The infant phase is characterized by rapid growth and curiosity with its surroundings. Both characteristics encourage the infant to explore, move about, play with others of similar size, grip objects, and learn survival skills (foraging techniques). All activities increase the muscle and bone strength of the individual. Within months the infant will be quite independent of the female. The precocial nature of the infant squirrel monkey allows for this rapid growth and maturation process.

As a juvenile squirrel monkey the individual is developing into just that, an individual within the species as a whole. The interactions of the juveniles not only promote growth, but encourage social development as well. Play is a means of developing strength and survival techniques. It is also used as a means of learning the hierarchy of the troop. The growth and development that takes place during this life stage is not consistent with each individual. As with other primates, the individual within the species develops according to nutritional factors, exercise, disease, and genetic backgrounds.

Once the squirrel monkey reaches the adult life stage, its physical development is almost complete. The term subadult refers to individuals who have not reached sexual maturity but demonstrate other examples of adulthood (tooth eruption). Full adult status is the onset of sexual maturity. The development of mating practices and the continuation of the troop population is one of the primary concerns of the adult stage. Part of this continuation of the troop involves teaching the infants and juveniles proper foraging techniques. For example, when a group of infants stopped to observe a black saturnyid caterpillar, an adult male placed himself between the caterpillar and the infants, then gave several warning barks (Boinski and Fragaszy 1989). The caterpillar was a toxic variety that would have caused severe illness or death of the infants.

A major portion of survival for the adult is the avoidance of predators. The squirrel monkey's ability to move quickly using its extremely strong hind legs is one of its greatest assets. The hindlimb represents 18% of the total body weight of the individual. This translates into power to propel the relatively small body of the squirrel monkey forward or in any direction necessary.

The implications in the differences in the body percentages, muscle volume, and the various indices influence the preparation for life in the trees (not on the mother's back) and for the reproductive phase of the adult's life. The shift in segment weight from the distal portion of the limbs in the infant to a significant increase in the trunk and proximal end of the hindlimb of the adult supports the change in life style from a protected individual gripping its mother's hair for life, to an individual that has the ability to protect itself through learned behaviors and movement capabilities.

The greatest changes that occur between the infant and adult life stages are in the distribution of the body tissues as shown in the following summation:

	Adult	Infant
%bone:tbw............	15.8	24.6
%muscle:tbw..........	41.3	20.9
%skin:tbw............	16.8	24.2
%other:tbw...........	24.7	24.7

The infant is very even in the distribution of the body tissues. The adult however, demonstrates a major shift toward increased musculature with a decrease in the skeletal weight and skin weight. This allows for greater speed and quickness for short distances but does not allow for extended periods of exertion due to a lack of stored energy (fat). This would be a primary reason for approximately 95% of an adult's day being spent foraging (Boinski 1987) for food in the form of fruits, nectars, and the highest energy food consumed by the squirrel monkey - small arthropods.

If the skeletal and muscular changes discussed in this paper did not occur, the squirrel monkey would not be able to develop the movement patterns necessary for survival as the type of primate they have evolved into. If the infant were simply a smaller version of the adult, there would be no change in the distribution of body tissues or changes in the body segments. The squirrel monkey would be a relatively slow, weak, and head-heavy primate lacking the muscular strength to hold it's head up. It would also have difficulty moving in the trees and would probably be confined to a terrestrial life style. This life style would more than likely be quite short, as its slowness and awkwardness would be an open invitation to predators sharing the region.

The changes in the body accommodate the changing life of the infant to the juvenile to the adult allowing for the quickness to develop, a weight appropriate to the preferred substrate, reproductive awareness, and a body that is at home in the terminal branches of the trees.

Educational component

Science education classes in the public schools are under siege from every aspect of the public (animal welfare activists, state and local budget concerns) to discontinue the use of preserved animals in comparative anatomy studies and resort to the use of computer simulations. School officials cite the increased cost of preserved materials as a waste of funds since such items are considered disposable purchases. They believe that the use of computer simulations would be a more practical use of school funds since the computer programs can be used year after year. Animal welfare activists would ban the use of animals in teaching and research programs citing the cruelty aspect of full body dissections. The animal welfare activists also support the use of computer simulations as a viable alternative.

Computer simulations, although cost effective, lack the real world connection to the biological sciences that allows for the actual hand-on learning that most students prefer and require in order to effectively understand the function of the various parts of animals. When students go to zoos or museums or work with their own pets, they are not looking at computer simulations but at real life animals. The level of understanding of the connections between animals and their environment are increased through proper anatomical studies of a variety of animals.

Comparative anatomy studies when properly conducted can provide the hands-on understanding of the evolutionary development of a variety of species. Dissecting and manipulation of the various parts of the individual animals develops the understanding of the function of the entire animal in terms of feeding behavior, group or individual survival techniques, and reproductive nature instead of a surface recognition of the species.

Through special arrangements, local zoos and living museums can provide various body parts or possibly whole animals (after postmortem examination) to be used in the classroom (Doolittle and Grand 1995). This type of arrangement can allow for the use of more exotic species in the classroom and can defer some cost of materials for the school district.

The following lesson is designed to be used in a high school biology class at the Freshmen/Sophomore level. It can be modified to be used in advanced biology studies also. The basis of the lesson is in comparative vertebrate anatomy, focusing on the skeletal and muscular development of the five vertebrate classes. Concentration on form and function and how they relate to the evolutionary development of the animals is the primary focus of the lesson.

TEACHER BACKGROUND

HUMAN ANATOMY

The preliminary studies in human anatomy will establish the basic knowledge needed for the future lab in vertebrate comparison. Any anatomy text will supply you with the basic information needed for the lessons on the different systems. Most Biology books will have a short chapter on the subject of human anatomy. A more extensive knowledge base in the area of the skeletal and muscular development is needed for the comparison lab.

An understanding of the location of the bones and muscles, the function of the bones and muscles, the origin and insertions of muscles, the types of connective tissue, and the types of joints and how they work is necessary.

The use of small plastic skeletons and clay will allow the students to build the systems that will be discussed. These can be obtained through local toy stores or through science catalog orders (See material list).

The discussions on the internal systems (excluding skeletal and muscular) are needed for support information in the understanding of the complete organism. The depth of coverage is entirely up to you and the requirements of your department.

Assignments from the Human Anatomy Coloring Book will aid in the understanding of location of bones, muscles, and system parts. A dissection of a chicken or turkey wing will demonstrate the working of antagonistic muscles (See student procedure). A means of demonstrating the overall workings of the mammalian internal systems would be through a dissection of the fetal pig. (See student procedure)

(A good specimen could be saved for the skeletal preserving technique discussed later.)

VERTEBRATE COMPARISON LAB

The laboratory activity involves a comparison of five different vertebrates. The lab procedures in this design are written for a pigeon, a turtle, a fetal pig, a perch, and a frog although any species from each group may be substituted. All five species will be dissected at the same time by different groups in the class. The general goal for each group is to collect data concerning specific bones and muscles and the functions of the bones and muscles of their species. All data will then be charted to compare the various structures and their functions. Your goal as a discussion facilitator is to allow the students to discover the similarities and differences in the species involved

Dissection manuals may be useful, but it is recommended that you use only diagrams of the musculature and skeleton. Too much information is confusing to the student (See materials list for suggested manuals).

Basic dissecting materials needed are small pointed scissors, a blunt probe, and a tray for the specimen (See materials list). Groups of 4-5 students working together will work best. If a larger class is to do the lab, an additional specimen may be needed. This number of students in a group will allow for a sharing of the duties required during the lab exercise. It is also recommended that the students trade roles often in order to allow everyone an opportunity to work directly with the dissection specimen.

The number of individual specimens will depend on the number of classes doing the lab (as in 3 classes:3 turtles). At least one of each species will need to be prepared for the skeletal analysis. (See preparation of the skeleton.) The lab specimens can be found in any science materials catalog. (See materials list for suggestions.)

The time allotment for the dissection part of the lab will be 2-3 class periods or if you can block schedule, 2-3 hours. This amount of time is necessary in order to allow the students ample time to explore and collect the needed data.

Allow 1-2 class periods for the discussion of the information collected by each group. Allowing each group to present their data is an excellent means to incorporate total class participation. The primary points your students should be looking for are: (list on board for discussion)

1) What skeletal structures do the vertebrates have in common?
2) Are these structures located in the same places?

3) Do these structures have a similar function in the different species?
4) What muscles do the vertebrates have in common?
5) Are these muscles located in the same places?
6) Do these muscles have a similar function in the different species?

These questions will have your students looking for the similarities in the growth and development of the different species. Questions as to whether or not they could be related (common ancestry) based on the skeletal and muscular development should be raised.

Time will need to be allotted in the future for a class comparison involving the data from the primate study (chimpanzee) and the human. The same questions as listed above will be used in the class discussion once the data from the chimpanzee and human have been added to the comparison chart. This section will open discussion in human evolution studies.

PRIMATE STUDIES

In preparing your discussion of the chimpanzee, you will need to have available diagrams, slides, or videos outlining the skeletal and muscular development of the this primate. Materials can be obtained through the University of Arizona Anthropology department. In most cases, skeletons (articulated and disarticulated) can be borrowed for short periods of time. This is at the discretion of the department.

The method of data collection will depend on the amount of material you are able to collect. If you are able to gather multiple diagrams of chimpanzee musculature and skeletons then groups of 4-5 students gathering individual data will work. If only one set of diagrams or one skeleton is found, then a class discussion involving the gathering of the data will be used.

HUMAN EVOLUTION STUDIES

A collection of creation stories from various cultures for comparison will be needed. These can be obtained through your local library or museums. Allow the student to compare these stories, then introduce the concept of human evolution as a means of explaining the presence of humans on the earth.

The video LIFE ON EARTH has an excellent section on the origin of living organisms (1:1-1:4). A reading in TIME magazine (March 14, 1994) titled How Man Began can be used.

Comparative Vertebrate Anatomy Lesson

LESSON BACKGROUND

Human anatomy studies

1. Video: The Incredible Human Machine
2. Group discussion on body systems
   - each group to discuss/diagram parts of the system chosen (include written descriptions)
   - group assignment turned in for later examination by group
3. Coverage of body systems
   - methods to include:
     - anatomy color plates for systems covered to be assigned at the beginning of each section
     - discussions on structure/functions of systems
       - focus on skeletal/muscular systems
       - relate to favorite activity
         - assignment:
           describe bones and muscles used to perform activity
       - use of articulated and disarticulated skeletons
       - building major muscle groups on

plastic skeletons using clay
(See materials list)
  - dissection of chicken wing to demonstrate muscles of opposition
    (See student procedure)
- building of systems (models from various materials:plastic, clay, paper)
- integration of models into one specimen.
- dissection of fetal pig for investigation of systems
  (See student procedure)
- original groups to
  discuss, diagram, and analyze original system from beginning of unit
- group presentations showing differences in perception of system
- evaluation of unit (See test section)
  - locating and naming of man parts of the systems
  - essay explanation of systems functions and the cooperative nature of the systems
  - application problem to describe

how movements or functions
happen in humans

Variety of species on Earth

1. introduction to physical relationships of various species (concentration of vertebrates)
   - discussion of embryonic development with a comparison of diagrams of various embryo
   - discussion of vertebrate heart structures
   - discussion of similarities in vertebrates (structure/behavior)
   - assignment: Examining Homologous and Analogous Structures
2. lab assignment
   - dissection of chicken/turkey wing
     - practice assignment for comparison lab (See student procedure)
   - comparison lab
     - groups of 5-6 students
     - each group to dissect a seperate specimen
       - five different vertebrates will be used
     - each group will collect data on

skeletal and muscular design

- location (origin/insertion)
- function

- data will be collected in chart form for each specimen
- all groups will complete a class comparison chart (data to be used by each group or individual in class)

- evaluation of lab
  - practical portion
    - I.D. of bones/muscles and stated functions for a dissected vertebrate at front desk
      - individual test
  - completion of individual lab report
    - diagrams
    - charts with data
    - interpretations

Vertebrate comparison preparation

(1-2 weeks prior to lab)

1. Skeletons of each of the species selected for this lab will need to be produced (if your department does not have mounted specimens). There are three methods that may be employed. Methods may be performed by students or by the teacher.
   - Place specimen in container with Dermestids (flesh eating beetles). Within one to two weeks, each skeleton will be usable. Some assembly of the skeleton will be necessary as the connective tissue can also be destroyed. (Permanent mounts can be made of these skeletons.)
     NOTE: Be careful not to let beetles escape as they can become pests.
   - Remove all organs and as much of the muscle tissue as possible. Be careful not to damage ligaments. Place the specimen in a beaker large enough to hold it. Mix 27 g of an enzyme presoak detergent (ERA, Tide, All) with 300 mL of water (increase proportionally to provide enough soak to cover specimen). Leave overnight. Next day, rinse with plain water. After rinse,

remove loose tissue with forceps.

Place specimen in a beaker and cover with chlorine bleach. After a few minutes, remove and rinse with plain water. Remove any loose tissue. **DO NOT LEAVE THE SKELETON IN THE BLEACH FOR EXTENDED PERIODS OF TIME. THE BLEACH WILL LOOSEN THE LIGAMENTS CAUSING THE SKELETON TO FALL APART.**

Continue the final step until all tissue is removed.

- For the purpose of this lab, degreasing is not necessary. If you are going to use the specimen for permanent mounts then you will need to drill small holes to the middle of the thicker portions of the bones. The next step will be to soak the clean bones in alcohol to extract the grease.

  This will take 1-2 days depending on the size and number of bones. Remove the bones from the alcohol and allow to dry.
- All tissue can be removed manually by the student. The use of scissors, forceps, and teasing needles will allow for tissue removal.

2. To mount the skeleton for viewing, select a

natural position for each specimen (some gluing or wire supports may be needed). Pin or glue the specimen to a piece of wood or heavy cardboard. Once the specimen is dry, a coating of spray shellac will preserve the specimen for future studies.

Vertebrate comparison lab (practice dissection)

Purpose:

To practice blunt dissection techniques for muscle separation and identification

Materials:

chicken or turkey leg/thigh	
scissors (pointed)	blunt probe
teasing needle	dissecting tray
forceps	

Procedure:

1. Remove leg from alcohol solution and rinse in clear water. Pat dry with paper towel.
2. Place leg in tray. Starting at the large end and using forceps, carefully lift the skin of the specimen. Place the pointed end of the scissors under the skin and open the scissors slowly. This will separate the connecting fibers from the muscle and the skin. Insert the one side of the open scissors under the skin and lift to insure you will not be cutting into the muscle tissue. Cut through the skin repeating the above process until

you completely remove the skin from the leg.

3. Locate the muscles of the anterior portion of the specimen. Using the blunt probe, carefully separate the surface muscles from each other.
   Draw the muscles of the specimen.
4. Label the drawing with the proper names for the muscles.
5. Dispose of the specimen in the proper fashion and clean your lab equipment and area.

Vertebrate comparison lab (amphibia)

Purpose:

To examine the skeletal and muscular development of a typical amphibian.

Materials:

frog

frog skeleton (previously prepared)

scissors	blunt probe
teasing needle	tray
colored pencils	metric ruler

Part I - Skeletal

Procedure:

1. Using the skeleton that was previously prepared as a model, draw the skeleton on the lab sheet provided. Label and color the major bones of the axial skeleton.
2. Label but do not color the major bones of the appendicular skeleton.
3. Create a chart listing the location and function of the bones of the axial skeleton and the appendicular skeleton
4. Create a chart listing the types of

joints, the location, and the movement capabilities of the joints found in the skeletal structure.

Part II - Muscular

Procedure:

1. Place your preserved specimen dorsal side up in the dissecting tray. Using forceps, lift a small section of skin at the base of the head. Make a small cut with the scissors.
2. Insert the point of the open scissors and lift gently making sure the scissors do not come in contact with the muscle tissue. Make a short cut in the direction of the pelvic region of the specimen. Insert the closed scissors under the skin and open them to release connective tissues between the skin and the muscles tissue. Continue the process down the length of the back.
3. Continue the process in step two moving down the legs, arms, and around the body. Use the blunt probe to assist in releasing the connective tissues.

Completely remove the skin using this process.

4. With the dorsal side up, diagram the major muscles of the back, the mouth, the back side of the arms, and the back of the pelvic region and hind legs. Label the major muscles of these regions. Consult the diagram of the frog muscular system if needed.
5. Turn the specimen over so the ventral side is up. Diagram the major muscles of the torso, the front side of the arms, the pelvic girdle, and the hind legs. Label the major muscles of these regions. Consult the diagram of the frog muscular system if needed.
6. Create a chart to show the origin, insertion, and the action created by the following muscles.

Biceps (or equivalent)	Triceps (or equivalent)
Pectoralis	Rectus abdominus
Masseter	Latissimus dorsi
Deltoid	External oblique
Gastrocnemius	Sartorius
Gluteals	Biceps femoris

Rectus femoris	Vastus externus
Vastus internus	Trapezius

7. Using the blunt probe, gently separate and extract each of the above muscles to determine the points of origin and insertion. Gently contract (pull) the muscle in the direction of the origin to determine the action of the muscle.
8. Is the muscular system of the amphibian a general or a specialized type of development? Explain why.
9. Combine the data from your charts with the data collected by the other groups.
10. Using the combined class data on the skeletal and muscular systems of the five vertebrates, do they share a common ancestry? Why/why not?

Vertebrate comparison lab (mammalia)

Purpose:

To examine the skeletal and muscular development of a typical mammal.

Materials:

fetal pig

fetal pig skeleton (previously prepared)

scissors	blunt probe
teasing needle	tray
colored pencils	metric ruler

Part I - Skeletal

Procedure:

1. Using the skeleton that was previously prepared as a model, draw the skeleton on the lab sheet provided. Label and color the major bones of the axial skeleton.
2. Label but do not color the major bones of the appendicular skeleton.
3. Create a chart listing the location and function of the bones of the axial skeleton and the appendicular skeleton
4. Create a chart listing the types of

joints, the location, and the movement capabilities of the joints found in the skeletal structure.

Part II - Muscular

Procedure:

1. Place your preserved specimen dorsal side up in the dissecting tray. Using forceps, lift a small section of skin at the base of the head. Make a small cut with the scissors.
2. Insert the point of the open scissors and lift gently making sure the scissors do not come in contact with the muscle tissue. Make a short cut in the direction of the pelvic region of the specimen. Insert the closed scissors under the skin and open them to release connective tissues between the skin and the muscles tissue. Continue the process down the length of the back.
3. Continue the process in step two moving down the legs, arms, and around the body. Use the blunt probe to assist in releasing the connective tissues.

Completely remove the skin using this process.

4. With the dorsal side up, diagram the major muscles of the back, the back side of the arms, and the back of the pelvic region and hind legs. Label the major muscles of these regions. Consult the diagram of the pig's muscular system if needed.
5. Turn the specimen over so the ventral side is up. Diagram the major muscles of the torso, the mouth the front side of the arms, the pelvic girdle, and the hind legs. Label the major muscles of these regions. Consult the diagram of the pig's muscular system if needed.
6. Create a chart to show the origin, insertion, and the action created by the following muscles.

Biceps (or equivalent)	Triceps (or equivalent)
Pectoralis	Rectus abdominus
Masseter	Latissimus dorsi
Deltoid	External oblique
Gastrocnemius	Sartorius
Gluteals	Biceps femoris

Rectus femoris	Vastus externus
Vastus internus	Trapezius

7. Using the blunt probe, gently separate and extract each of the above muscles to determine the points of origin and insertion. Gently contract (pull) the muscle in the direction of the origin to determine the action of the muscle.
8. Is the muscular system of the mammal a general or a specialized type of development? Explain why.
9. Combine the data from your charts with the data collected by the other groups.
10. Using the combined class data on the skeletal and muscular systems of the five vertebrates, do they share a common ancestry? Why/why not?

Vertebrate comparison lab (bony fish)

Purpose:

To examine the skeletal and muscular development of a typical bony fish.

Materials:

perch	perch skeleton (previously prepared)
scissors	blunt probe
teasing needle	tray
colored pencils	metric ruler

Part I - Skeletal

Procedure:

1. Using the skeleton that was previously prepared as a model, draw the skeleton on the lab sheet provided. Label and color the major bones of the axial skeleton.
2. Label but do not color the major bones of the appendicular skeleton.
3. Create a chart listing the location and function of the bones of the axial skeleton and the appendicular skeleton
4. Create a chart listing the types of

joints, the location, and the movement capabilities of the joints found in the skeletal structure.

Part II - Muscular

Procedure:

1. Place your preserved specimen ventral side up in the dissecting tray. Using forceps, lift a small section of skin at the base of the tail fin. Make a small cut with the scissors.
2. Insert the point of the open scissors and lift gently making sure the scissors do not come in contact with the muscle tissue. Make a short cut in the direction of the pectoral region of the specimen. Insert the closed scissors under the skin and open them to release connective tissues between the skin and the muscles tissue. Continue the process up the length of the belly.
3. Continue the process in step two moving around the body. Use the blunt probe to assist in releasing the connective tissues. Completely remove the skin

using this process.

4. With the dorsal side up, diagram the major muscles of the back, the tail, and the mouth. Label the major muscles of these regions. Consult the diagram of the fish muscular system if needed.
5. Turn the specimen over so the ventral side is up. Diagram the major muscles of the torso, the tail, and the muscles surrounding the lateral fins. Label the major muscles of these regions. Consult the diagram of the fish muscular system if needed.
6. Create a chart to show the origin, insertion, and the action created by the following muscles.

Biceps (or equivalent)	Triceps (or equivalent)
Pectoralis	Rectus abdominus
Masseter	Latissimus dorsi
Deltoid	External oblique
Gastrocnemius	Sartorius
Gluteals	Biceps femoris
Rectus femoris	Vastus externus
Vastus internus	Trapezius

7. Using the blunt probe, gently separate and extract each of the above muscles to determine the points of origin and insertion. Gently contract (pull) the muscle in the direction of the origin to determine the action of the muscle.
8. Is the muscular system of the bony fish a general or a specialized type of development? Explain why.
9. Combine the data from your charts with the data collected by the other groups.
10. Using the combined class data on the skeletal and muscular systems of the five vertebrates, do they share a common ancestry? Why/why not?

Vertebrate comparison lab (aves)

Purpose:

To examine the skeletal and muscular development of a typical bird.

Materials:

pigeon	pigeon skeleton (previously prepared)
scissors	blunt probe
teasing needle	tray
colored pencils	metric ruler

Part I - Skeletal

Procedure:

1. Using the skeleton that was previously prepared as a model, draw the skeleton on the lab sheet provided. Label and color the major bones of the axial skeleton.
2. Label but do not color the major bones of the appendicular skeleton.
3. Create a chart listing the location and function of the bones of the axial skeleton and the appendicular skeleton
4. Create a chart listing the types of

joints, the location, and the movement capabilities of the joints found in the skeletal structure.

Part II - Muscular

Procedure:

1. Place your preserved specimen dorsal side up in the dissecting tray. Using forceps, lift a small section of skin at the base of the head. Make a small cut with the scissors.
2. Insert the point of the open scissors and lift gently making sure the scissors do not come in contact with the muscle tissue. Make a short cut in the direction of the pelvic region of the specimen. Insert the closed scissors under the skin and open them to release connective tissues between the skin and the muscles tissue. Continue the process down the length of the back.
3. Continue the process in step two moving down the legs, wings, and around the body. Use the blunt probe to assist in releasing the connective tissues.

Completely remove the skin using this process.

4. With the dorsal side up, diagram the major muscles of the back, the back side of the wings, and the back of the pelvic region and hind legs. Label the major muscles of these regions. Consult the diagram of the pigeon's muscular system if needed.
5. Turn the specimen over so the ventral side is up. Diagram the major muscles of the torso, the front side of the wings, the pelvic girdle, and the hind legs. Label the major muscles of these regions. Consult the diagram of the pigeon's muscular system if needed.
6. Create a chart to show the origin, insertion, and the action created by the following muscles.

Biceps (or equivalent)	Triceps (or equivalent)
Pectoralis	Rectus abdominus
Masseter	Latissimus dorsi
Deltoid	External oblique
Gastrocnemius	Sartorius
Gluteals	Biceps femoris

Rectus femoris	Vastus externus
Vastus internus	Trapezius

7. Using the blunt probe, gently separate and extract each of the above muscles to determine the points of origin and insertion. Gently contract (pull) the muscle in the direction of the origin to determine the action of the muscle.
8. Is the muscular system of the pigeon a general or a specialized type of development? Explain why.
9. Combine the data from your charts with the data collected by the other groups.
10. Using the combined class data on the skeletal and muscular systems of the five vertebrates, do they share a common ancestry? Why/why not?

Vertebrate comparison lab (reptilia)

Purpose:

To examine the skeletal and muscular development of a typical reptile.

Materials:

turtle	turtle skeleton (previously prepared)
scissors (small and heavy)	
blunt probe	
teasing needle	tray
colored pencils	metric ruler

Part I - Skeletal

Procedure:

1. Using the skeleton that was previously prepared as a model, draw the skeleton on the lab sheet provided. Label and color the major bones of the axial skeleton.
2. Label but do not color the major bones of the appendicular skeleton.
3. Create a chart listing the location and function of the bones of the axial skeleton and the appendicular skeleton

4. Create a chart listing the types of joints, the location, and the movement capabilities of the joints found in the skeletal structure.

Part II - Muscular

Procedure:

1. Place your preserved specimen ventral side up in the dissecting tray. Using heavy scissors or a saw, cut the sides of the turtle shell being very careful not to cut any skin tissue. Remove the ventral portion of the shell. Remove as much of the shell as possible. It may be necessary to cut around the front and the back legs to release the shell.
2. With the ventral side up, diagram the major muscles of the abdominal region, the back side of the arms, and the back of the pelvic region and hind legs. Label the major muscles of these regions. Consult the diagram of the turtle's muscular system if needed.
3. Turn the specimen so the lateral side is up. Diagram the major muscles of the

mouth the front side of the arms, the pelvic girdle, and the hind legs. Label the major muscles of these regions. Consult the diagram of the turtle's muscular system if needed.

4. Create a chart to show the origin, insertion, and the action created by the following muscles.

Biceps (or equivalent)	Triceps (or equivalent)
Pectoralis	Rectus abdominus
Masseter	Latissimus dorsi
Deltoid	External oblique
Gastrocnemius	Sartorius
Gluteals	Biceps femoris
Rectus femoris	Vastus externus
Vastus internus	Trapezius

7. Using the blunt probe, gently separate and extract each of the above muscles to determine the points of origin and insertion. Gently contract (pull) the muscle in the direction of the origin to determine the action of the muscle.
8. Is the muscular system of the reptile a general or a specialized type of

development? Explain why.

9. Combine the data from your charts with the data collected by the other groups.
10. Using the combined class data on the skeletal and muscular systems of the five vertebrates, do they share a common ancestry? Why/why not?

Primate study

1. Discussion on primates and what it means to be a primate.
   - video: Primates of the World
   - speaker: (contact local university or college)
2. Observation of primate structures
   - assignment: Observing Primate Structures (comparison of human to other primates)
   - articulated and disarticulated skeletons of small primates
     - groups assemble parts of disarticulated chimp skeleton
     - upon completion of each part, the groups will assemble the entire structure
3. Assignment:

   Diagram of chimpanzee skeleton with major bones labeled. Axial skeleton to be colored.
4. Assignment:

   Create a chart listing the location and the function of the bones of the axial and appendicular skeleton.
5. Assignment:

   Create a chart listing the types of joints, the location, and the movement capabilities of the joints found in the chimpanzee skeleton.

6. Discussion on musculature of chimpanzees
   - slides/overheads/xerox copies on musculature of chimpanzee
   - video: Life on Earth (Life in the Trees) (highlights movement patterns of monkeys)
7. Assignment:
   Create a chart to show the origin, insertion, and the action created by the following muscles.

Biceps (or equivalent)	Triceps (or equivalent)
Pectoralis	Rectus abdominus
Masseter	Latissimus dorsi
Deltoid	External oblique
Gastrocnemius	Sartorius
Gluteals	Biceps femoris
Rectus femoris	Vastus externus
Vastus internus	Trapezius

8. Is the muscular system of the chimpanzee a general or a specialized type of development? Explain why.
9. Class project:
   - Need class charts from vertebrate

comparison lab. Add information from chimpanzee.

- Class discussion on relatedness of specimens based on skeletal and muscular development.
- Introduction of information on human skeletal and muscular development into vertebrate chart.
    - class discussion on topic of relatedness to other vertebrates on the chart

10. Final evaluation
    - Each student is to state their concept of the relationship between man and other vertebrates. Is there or is there not a common ancestry to the species examined in the comparison lab (including the chimpanzee and man) based on skeletal and muscular development. Defend your statement using information found in the data charts from lab or scientific information from other sources. (Be sure you state your source of information.)

<u>Human evolution studies</u>

1. Discussion of personal concepts of where man came from
   - what is evolution?
   - discussion of creationist concepts
     - include creation stories from other cultures
   - discussion of evolutionary concepts
     - comparisons of Biblical accounts with those of fossil findings
     - discussion of fossil dating
       - assignment on fossil dating
     - video: Life on Earth (1:1-1:4)
   - reading: How Man Began
     - reaction/interpretation essay
2. Development of personal concept of human origin
   - written essay with supportive arguments

APPENDIX A

Pelage and region					
	S.s. sciureus	*S.s. boliviensis*	*S.s. cassiquiarensis*	*S.s oerstedii*	*Saimiri madeirae*
PELAGE	gray crowns; yellowish-tawny backs; broad patch of white over eyes; yellow on forearm to elbow	black crown; orange or yellowish back extending to limbs; narrower patch of white over eyes	olive to tawny crown; yellowish-white collar to separate crown and back; broad patch of white over eyes	gray crowns; gray limbs; golden-orange back; broad patch of white over eyes	clear gray crown with blue tone; blue-gray forearms; broad patch of white over eyes
REGION	Guianas from Brazil north of the Amazon and east of the Rio Negro and Brazil south of the Amazon and eastof the Xingu River. Columbia, Ecuador, northern Peru, Brazil	Bolivia, Peru, Brazil. Much of Bolivia, in Peru north to approx. 7^{o}S and in Brazil between the Jurua and Purus Rivers north to the Amazon	Amazonas, Venezuela,Codajaz Brazil on the north bank of the Amazon west of the Rio Negro and Cacao Pereira Igarape, Brazil west of the Rio Negro near Manaus	Panama, Costa Rica	Humayta on the west bank of the Rio Madeira. Along the Rio Madeira, west to the Rio Purus, and east toward the Rio Tapajos

APPENDIX B

EXTERNAL BODY MEASUREMENTS

Saimiri sciureus No.______ Dissection date______________________

Sex: M F Date of birth ______________ Age in mos.________

Infant / Adult Researchers ____

____

TOTAL BODY WEIGHT (TBW) _____________________

TOTAL BODY LENGTH _____________________

TRUNK

TRUNK LENGTH _______________

SHOULDER BREADTH _______________

HIP BREADTH _______________

TAIL LENGTH _______________

FORELIMB

TOTAL LENGTH ________

UPPER ARM LENGTH ____

FOREARM LENGTH ____

HAND LENGTH ____

THUMB LENGTH ____

HAND BREADTH ____

HEAD

HEAD LENGTH _______________

HEAD BREADTH _______________

FACE BREADTH _______________

FACE HEIGHT _______________

HINDLIMB

TOTAL LENGTH ____

THIGH LENGTH ____

LEG LENGTH ____

FOOT LENGTH ____

FOOT BREADTH ____

HALLUX LENGTH ____

CIRCUMFERENCES

HEAD ______________

CHEST ______________

UPPER ARM ______________

FOREARM ______________

THIGH ______________

LEG ______________

TAIL ______________

DENTITION

DECIDUOUS

UPPER ___________

LOWER ___________

PERMANENT

UPPER ___________

LOWER ___________

HEAD

<u>Saimiri sciureus</u>

No.________ Sex: M F Infant / Adult

Date: ______________

Total Body Weight __________________

Remarks:____

____

Total head weight		__________
Percentage of Total Body Weight (TBW)		__________
Skin of head segment weight	__________	__________%
Muscle of mastication	<u>right</u>	<u>left</u>
masseter	__________	__________
temporal	__________	__________
pterygoids	__________	__________
total	__________	__________
		__________% segment weight
Miscellaneous tissues	__________	__________% segment weight
Tongue and associated muscles	__________	__________% segment weight
Eyes	__________	__________% segment weight
Brain	__________	__________% segment weight
Cranial capacity	__________	

Skull	__________	__________% segment weight
Mandible	__________	__________% segment weight

TRUNK
(part I)

Saimiri sciureus

No. __________ Sex: M F Infant / Adult

Date: ______________

TBW __________________

Remarks____

____

I. SEGMENT: RIGHT / LEFT / WHOLE _______total weight

Skin ____________ ______% segment

Muscle ____________ ______% segment

1) Trunkbinding
2) Trunk extensors
3) 'Other'
4) Hip

Bone ____________ ______% segment

1) Vertebrae ____________

2) Scapula/Clavicle ____________

3) Hip ____________

Internal organs ____________ ______% segment

Total (muscle, bone, organs)____________ ______% of TBW

(TRUNK cont.)

Saimiri sciureus

No. ___________ Sex: M F Infant / Adult

Date: ___________________

TBW_______________

II. MUSCLE-BY-MUSCLE: RIGHT / LEFT / WHOLE

A. Trunk binding

trapezius	_____________	
rhomboids	_____________	
atlantoscapularis	_____________	(anterior)
	_____________	(posterior)
serratus anterior	_____________	

Rotator cuff:

subscapularis	_____________
supraspinatus	_____________
infraspinatus	_____________
teres minor	_____________
teres major	_____________
latissimus dorsi	_____________
pectoralis major	_____________
pectoralis minor	_____________
pectoralis abdominalis	_____________
subclavis	_____________
Total muscle weight	_____________
	___________% TBW

Bone (clavicle/scapula/vert) ____________

____________% TBW

Skin ____________

____________% TBW

Fat ____________

____________% TBW

(TRUNK cont.)

Saimiri sciureus

No. ______________ Sex: M F Infant / Adult

Date:______________

TBW______________

II. MUSCLE-BY-MUSCLE RIGHT / LEFT / WHOLE

B. Extensors of trunk

cervical __________

thoracic __________

lumbar __________

sacral/caudal __________

Total __________ __________% segment

C. Abdominals

rectus abdominus
external oblique
internal oblique
transversus abdominis
pyramidalis

Total ____________

D. Intercostals

external
internal
serratus anterior

Total ____________

E. Neck flexors

sternomastoid
cleidomastoid
cleido-occipitalis
digastricus
sternohyoid
scalenes group

Total ____________

F. Trunk flexors

quadratus lumborum ______________

G. Masticatory muscles
(see HEAD) ______________

Total (1, 2, 3, 4, 5) __________

_______% segment

(TRUNK cont.)

Saimiri sciureus

No. ______________ Sex: M F Infant / Adult

Date: ______________

TBW ______________

H. Hip musculature
(see HIP) __________

_______% segment

Total muscle weight __________

Fat & other __________

Skin __________

Bone __________

UPPER ARM

<u>Saimiri sciureus</u>

No. ______________ Sex: M F Infant / Adult

Date: ______________

TBW ______________

Segment weight before dissection ________________

REMARKS ____

____

I. SEGMENT: RIGHT / LEFT / WHOLE

muscle	____________		____________ % segment
skin & fat	____________		____________ % segment
bone	____________	(humerus)	____________ % segment
TOTAL	____________		____________ % TBW

II. MUSCLE-BY-MUSCLE RIGHT / LEFT / WHOLE

biceps brachii		____________
long head	________	
short head	________	
coracobrachialis		____________
brachialis		____________
triceps		____________
long head	________	
medial head	________	
lateral head	________	
dorso-epitroclearis		____________

deltoid ______________

cleidodeltoid _______

acromiodeltoid ______

spinodeltoid _______

TOTAL MUSCLE WEIGHT ________________

FOREARM

Saimiri sciureus

No. ______________ Sex: M F Infant / Adult

Date: ______________

TBW______________

Segment weight before dissection ________________

REMARKS____

I. SEGMENT: RIGHT / LEFT / WHOLE

muscle	______________	______% segment
skin & fat	______________	______% segment
bone	______________	______% segment
(radius ______________ / ulna ____________)		
TOTAL	____________	______% TBW

II. MUSCLE-BY-MUSCLE RIGHT / LEFT / WHOLE

pronator quadratus	_______________
brachio-radialis	_______________
ext. carpi radialis longus	_______________
ext. carpi radialis brevis	_______________
ext. digitorum communis	_______________
ext. digiti minimi	_______________
ext. carpi ulnaris	_______________
ext. indicis	_______________
ext. pollicis longus	_______________
ext. pollicis brevis	_______________
abductor pollicis longus	_______________
flex. pollicis longus	_______________

flex. carpi radialis	______________
flex. digitorum sublimis	______________
flex. digitorum profundus	______________
flex. carpi ulnaris	______________
palmaris longus	______________
supinator	______________
anconeus	______________
pronator teres	______________
TOTAL MUSCLE WEIGHT	______________

HAND

<u>Saimiri sciureus</u>

No. ______________ Sex: M F Infant / Adult

Date: ______________

TBW ______________

Segment weight before dissection ________________

REMARKS ____

____

I. SEGMENT: RIGHT / LEFT / BOTH

muscle	______________	______% segment
skin & fat	______________	______% segment
bone (carpals, metacarpals, phalanges)	______________	______% segment
TOTAL	______________	______% TBW

II. MUSCLE-BY-MUSCLE RIGHT / LEFT / BOTH

abductor pollicis brevis	________________
flex. pollicis brevis	________________
adductor pollicis	________________
dorsal interossei	________________
palmar interossei	________________
lumbricales	________________
opponens pollicis	________________
flex. pollicis brevis profundus	________________
TOTAL MUSCLE WEIGHT	________________

PELVIS

Saimiri sciureus

No. ______________ Sex: M F Infant / Adult

Date: ______________

TBW ______________

Segment weight before dissection ______________

REMARKS ____

____

I. SEGMENT: RIGHT / LEFT / WHOLE

muscle	______________	______% segment
skin & fat	______________	______% segment
no bone (innominate is with trunk)		
Total	______________	______% TBW

II. MUSCLE-BY-MUSCLE RIGHT / LEFT / WHOLE

gluteus maximus	______________
gluteus medius	______________
gluteus minimus	______________
tensor faciae latae	______________
pyriformis	______________
gemelli (superior/inferior)	______________
obturator (internus/externus)	______________
psoas major	______________
psoas minor	______________
TOTAL MUSCLE WEIGHT	______________

THIGH

<u>Saimiri sciureus</u>

No. ____________ Sex: M F Infant / Adult

Date:____________

TBW____________

Segment weight before dissection ______________

REMARKS____

____

I. SEGMENT: RIGHT / LEFT / BOTH

muscle	____________	_____% segment
skin & fat	____________	_____% segment
bone (femur)	____________	_____% segment
Total	____________	_____% TBW

II. MUSCLE-BY-MUSCLE RIGHT / LEFT / BOTH

biceps femoris	______________
semitendinosus	______________
semimembranosus	______________
rectus femoris	______________
vastus lateralis	______________
vastus medialis	______________
vastus intermedius	______________
sartorius	______________
pectineus	______________
gracilis	______________

adductor magnus ____________________

adductor longus ____________________

TOTAL MUSCLE WEIGHT ____________________

____________%TBW

LEG

Saimiri sciureus

No. ______________ Sex: M F Infant / Adult

Date: ______________

TBW ______________

Segment weight before dissection ______________

REMARKS ____

____

I. SEGMENT: RIGHT / LEFT / BOTH

muscle	______________	______% segment
skin & fat	______________	______% segment
bone	______________	______% segment

(tibia _________ / fibula _________ / patella ______)

Total	______________	______% TBW

II. MUSCLE-BY-MUSCLE RIGHT / LEFT / BOTH

gastrocnemius	________________
plantaris	________________
soleus	________________
popliteus	________________
flex. fibularis (hallucis longus)	________________
flex. tibialis (longus)	________________
tibialis anterior	________________
tibialis posterir	________________
ext. digitorum longus	________________
ext. hallucis longus	________________

peroneus longus ____________________

peroneus brevis ____________________

TOTAL MUSCLE WEIGHT ____________________

________________% TBW

FOOT

Saimiri sciureus

No. ______________ Sex: M F Infant / Adult

Date:______________

TBW______________

Segment weight before dissection ______________

REMARKS____

____

I. SEGMENT: RIGHT / LEFT / BOTH

muscle	______________	______% segment
skin & fat	______________	______% segment
bone (tarsals, metatarsal, phalanges)	______________	______% segment
Total	______________	______% TBW

II. MUSCLE-BY-MUSCLE RIGHT / LEFT / BOTH

abductor hallucis	______________
adductor hallucis	______________
ext. hallucis brevis (digitorum)	______________
flex. hallucis brevis	______________
flex. digitorum brevis	______________
quadratus plantae	______________
abductor digiti minimi	______________
flex. digiti minimi brevis	______________
lumbricales	______________
contrahente digitorum pedis	______________

interossei (dorsal/plantar) ________________

TOTAL MUSCLE WEIGHT ______________

______________%TBW

TAIL

Saimiri sciureus

No. ____________ Sex: M F Infant / Adult

Date: ____________

TBW ____________

Segment weight before dissection ______________

REMARKS ____

____

I. SEGMENT: RIGHT / LEFT / WHOLE

muscle	____________	______% segment
skin & fat	____________	______% segment
bone	____________	______% segment
Total	____________	______% TBW

Appendix C

Saimiri sciureus No.________ Date_______________

Sex: M F Date of birth_____________ Age_______

Infant / Adult Researchers_________________________

SKELETAL MEASUREMENTS

Measurement key

1. Linear measurements of bone and teeth measured in centimeters and end with the following:
   - a. L length
   - b. B breadth
   - c. H height
   - d. DL diaphyseal length
   - e. MD midshaft diameter (based on diaphyseal length)
   - f. AP anterior-posterior
   - g. ML medial-lateral
   - h. PD proximal-distal

2. Bone weight measured in grams and end with the following:
   - a. BW

Linear measurements: Dentition Side: Right

1. M^2L ______________cm (mesial-distal length)
2. M^2B ______________cm (buccal-lingual breadth)
3. M_2L ______________cm
4. M_2B ______________cm

Linear measurements: Cranium and face

1. SL ______________cm (skull length, glabella to inion)
2. SBL ______________cm (skull base, basion to inion)
3. BZB ______________cm (bizygomatic)

Linear measurements: Post-cranial Side: Right

1. CL ______________cm (clavicle, maximum length)
2. CDL ______________cm (clavicle, diaphyseal length)
3. SML ______________cm (morphological length, glenoid fossa-root of spine)
4. HL ______________cm (humerus length)
5. HDL ______________cm (diaphyseal length)
6. HMDAP ____________cm (midshaft diameter A-P)
7. HMDML ____________cm (midshaft diameter M-L)
8. UL ______________cm (ulna,maximum length to styloid)

9. UTL ________________cm (midpoint trochlea to distal head)

10. UDL ________________cm (diaphyseal length)

11. RL(1) ______________cm (radius, maximum length to styloid)

12. RL(2) ______________cm (head to radial fossa)

13. RDL ________________cm (diaphyseal length)

14. FL(1) ______________cm (femur head to distal medial condyle)

15. FL(2) ______________cm (greater trochanter to distal epicondyle)

16. FDL ________________cm (diaphyseal length)

17. FMDAP ______________cm (midshaft diameter, A-P)

18. TL(1) ______________cm (tibia, maximum length to malleolus)

19. TL(2) ______________cm (facet to distal articular surface)

20. TDL ________________cm (diaphyseal length)

21. OS COXA ____________cm (maximum length, most proximal point of acetabulum to proximal extent of ilium)

22. IB ________________cm (ilium breadth)

<u>Bone weight:</u> (individual bones from the right side)

1. CWBW ________________g (skull-cranium)
2. MBW ________________g (mandible)
3. RCLBW ________________g (clavicle)
4. RSBW ________________g (scapula)
5. RHBW ________________g (humerus)
6. RRBW ________________g (radius)
7. RUBW ________________g (ulna)
8. RHWBW ________________g (hand and wrist)
9. RFBW ________________g (femur)
10. RTBW ________________g (tibia)
11. RFIBW ________________g (fibula)
12. RFOABW ________________g (foot and ankle)
13. IBW ________________g (os coxa, whole)
14. VBW ________________g (vertebrae, whole)
15. TLBW ________________g (tail)

APPENDIX D

INDIVIDUAL

MUSCLE WEIGHTS

	Specimen 1 adult male TBW 937.6g	Specimen 2 adult female· TBW 661.0g	Specimen 3 (s)adult male TBW 545.0g	Specimen 4 infant male TBW 108.1g	Specimen 5 infant male TBW 102.1G
HEAD					
weight / % tbw	98.2g/10.5%	67.4g/10.2%	77.2g/14.2%	31.4g/29.0%	24.7/24.2
muscles of mastication					
masseter r/l	1.8/1.4	0.8/0.7	0.8/0.9	0.1/0.1	0.1/0.1
temporal r/l	5.1/5.2	2.0/2.3	2.1/2.0	0.1/0.1	0.2/0.1
pterygoids r/l	0.5/0.6	0.2/0.3	0.3/0.2	<0.1/<0.1	<0.1/<0.1
buccinator r/l	0.2/0.1	0.1/0.1	0.1/0.1	<0.1/<0.1	<0.1/<0.1
total / % segment wt	14.9g/15.2%	6.5g/9.6	6.5g/8.4%	0.6g/1.9%	0.7g/2.8%
TRUNK					
weight / % tbw	425.8g/45%	374.8g/56.7%	256.5g/47.1%	43.3g/40.0%	40.9g/40.0%
trunk binding					
trapezius	3.3	1.6	1.4	0.1	0.1
rhomboids	1.1	0.8	0.6	0.1	0.1
atlantoscapularis (a)	0.4	0.2	0.1	0.1	<0.1
atlantoscapularis (p)	0.1	0.1	0.2	<0.1	<0.1
serratus anterior	2.1	1.6	1.8	0.1	<0.1

rotator cuff					
subscapularis	3.3	2.4	2	0.1	0.1
supraspinatus	1.4	1	0.7	0.1	0.1
infraspinatus	2	0.8	0.7	<0.1	<0.1
teres minor	0.5	0.1	0.2	<0.1	<0.1
teres major	2.2	1.4	1.2	0.1	0.1
latissumus dorsi	4.8	2.6	2.4	0.2	0.1
pectoralis major	3.9	2.9	2	0.2	0.1
pectoralis minor	0.8	0.4	0.5	0.1	0.1
pectoralis abdominalis	0.6	0.4	0.3	0.1	<0.1
subclavis	0.1	0.1	0.1	0.1	<0.1
total / % segment wt.	26.6g/6.2%	16.4g/4.4%	14.2g/5.5%	1.55g/3.6%	1.15g/2.8%
% tbw	2.8	2.5	2.6	1.4	1.1
trunk extensors					
cervical	4	1.8	1.2	0.5	0.2
thoracic	5	3.3	4.3	0.5	0.2
lumbar	13.8	9.5	5	0.3	0.1
sacral	14.4	9.2	6.4	0.8	0.7
abdominals					
rectus abdominus					
external oblique					
internal oblique					
transversus abdominis					
pyramidalis	15.8	18.7	9.3	0.6	0.5

intercostals					
external					
internal	7	7	3.3	0.6	0.2
neck flexors					
sternomastoid					
cleidomastoid					
cleido-occipitalis					
digastricus					
sternohyoid					
scalenes group	3.5	2.5	1.6	0.4	0.3
total / % trunk segment	26.3g/6.1%	28.2g/7.5%	14.2g/5.5%	1.6g/3.7%	1.0g/2.4%

FORELIMB (arm)					
weight / % tbw	52.9g/5.6%	32.6g/4.9%	30.4g/5.6%	5.5g/5.1%	6.5g/6.0%
upper arm					
upper arm segment weight	27.6g	15.8g	14.7g	2.4g	2.4g
biceps brachii	3.3	2.4	1.5	0.1	0.1
coracobrachialis	0.2	0.1	0.2	0.1	<0.1
brachialis	1.9	0.7	0.8	0.1	0.1
triceps brachii	8	5.1	4.3	0.3	0.2
dorso-epitroclearis	0.7	0.4	0.3	<0.1	<0.1
deltoid	2	1.6	1.3	0.1	0.1
total/% upper arm seg.	16.1g/58.3%	10.3g/65.2%	8.4g/57.1%	0.75g/31.25%	0.6g/25.0%
% total arm segment	30.4	31.2	48.4	11.5	9.2
forearm					
forearm segment weight	20.8g	12.0g	11.1g	2.3g	2.6g
pronator quadratus	0.1	0.1	0.1	<0.1	<0.1
brachio-radialis	2.1	1.2	0.6	0.1	0.1
ext. carpi radialis longus	0.8	0.4	0.4	<0.1	<0.1
ext. carpi radialis brevis	1	0.3	0.4	<0.1	<0.1
ext. digitorum communis	0.7	0.3	0.3	0.1	0.1
ext. digiti minimi	0.1	<0.1	<0.1	<0.1	<0.1
ext. carpi ulnaris	0.2	0.2	0.1	<0.1	<0.1
abductor pollicis longus	0.3	0.2	0.1	<0.1	<0.1
flex. pollicis longus	0.4	0.2	0.1	<0.1	<0.1
flex. carpi radialis	1	0.3	0.4	0.1	<0.1
flex. digitorum sublimis	0.2	<0.1	0.7	<0.1	<0.1

flex. digitorum profundus	3.2	3.1	2.4	0.2	0.1
flex. carpi ulnaris	1	0.6	0.7	0.1	0.1
palmaris longus	1.5	0.5	0.4	0.1	<0.1
supinator	0.2	<0.1	0.2	<0.1	<0.1
pronator teres	0.5	0.1	0.2	<0.1	<0.1
total / % forearm seg.	13.3g/63.9%	7.65g/63.8%	7.15g/64.4%	1.2g/52.1%	1.05g/40.3%
% total arm segment	25.1	23.2	23.5	18.6	16.2
hand					
hand segment weight	4.5g	4.8g	4.6g	1.8g	1.4g
abductor pollicis brevis					
flex. pollicis brevis					
opponens pollicis	0.15	0.15	0.2	<0.1	
adducotor pollicis	<0.1	<0.1	<0.1	<0.1	
dorsal interossei					
palmar interossei	0.1	0.1	0.1	<0.1	
lumbricales	<0.1	<0.1	<0.1	<0.1	0.1
total / % hand seg.	0.35g/7.8%	0.35g/7.3%	0.4g/8.7%	0.2g/11.0%	0.1g/7.1%
% total arm segment	0.66	1.1	1.3	3.1	1.5

PELVIS

gluteus maximus	4	2.5	1.9	0.1	0.1
gluteus medius	3	2.4	1.3	0.1	0.1
gluteus minimus	1.2	0.4	0.2	<0.1	<0.1
tensor faciae latae	1	0.5	0.6	<0.1	<0.1
pyriformis	<0.1	<0.1	<0.1	<0.1	<0.1
gemelli (sup. & inf.)	<0.1	<0.1	<0.1	<0.1	<0.1
obturator (int. & ext.)	0.7	0.6	0.4	0.2	0.1
psoas major	3.7	2.1	1.4	0.1	0.1
psoas minor	0.7	0.6	0.5	0.1	0.1
total / % tbw	14.4g/1.5%	9.2g/1.4%	6.4g/1.2%	0.8g/0.7%	0.7g/0.69%

HINDLIMB (leg)					
weight / % tbw	87.2g/9.3%	55.9g/8.5%	49.3g/9.0%	6.8g/6.3%	7.4g/7.2%
thigh					
thigh segment weight	53.9g	33.1g	29.5g	3.1g	2.8g
biceps femoris	5.1	3.6	2.7	0.1	0.1
semitendinosus	3.7	1.6	1.4	0.2	0.2
semimembranosus	10.5	7	5.3	0.2	0.2
rectus femoris	3.6	2.5	1.7	0.1	0.2
vastus lateralis	6	3.3	3.9	0.2	0.1
vastus medialis	1.9	1	0.9	0.1	0.1
vastus intermedius	1.7	1.1	0.8	<0.1	0.1
sartorius	1.5	0.8	0.9	0.1	0.1
pectineus	1	0.1	0.4	<0.1	<0.1
gracilis	2.4	1.4	1.4	0.2	0.1
adductor magnus	2.8	1.9	2.1	0.1	0.1
adductor longus	0.4	0.3	0.3	<0.1	<0.1
total / % thigh seg.	40.6g/75.3%	24.6g/74.3%	21.8g/73.9%	1.45g/46.8%	1.4g/50%
% hindlimb	46.6	44	44.2	21.3	18.9
leg					
leg segment weight	23.9g	15.0g	13.0g	2.3g	2.5g
gastrocnemius	4.3	2.3	2.3	0.1	0.1
plantaris	0.3	0.1	0.2	<0.1	<0.1
soleus	1.6	0.2	0.8	0.1	0.1
popliteus	0.3	0.2	0.2	<0.1	<0.1
flex. fibularis	0.8	1.4	0.2	0.2	<0.1

flex. tibialis (longus)	1.9	0.6	0.6	0.1	0.1
tibialis anterior	2.4	1.5	1.2	0.2	0.1
tibialis posterior	0.3	0.3	1	<0.1	<0.1
ext. digitorum longus	0.8	0.3	0.2	0.1	0.1
ext. hallicis longus	0.3	0.1	0.1	<0.1	<0.1
peroneus longus	0.7	0.6	0.4	<0.1	<0.1
peroneus brevis	0.4	0.1	0.1	<0.1	<0.1
total / % leg segment	14.1g/59%	7.7g/51.3%	7.3g/56.2%	1.1g/47.8%	0.85g/34.0%
% hindlimb segment	16.1	13.8	14.8	16.2	11.5
foot					
foot segment weight	9.4g	7.8g	6.8g	1.4g	2.1g
abductor hallicis					
adductor hallucis					
ext. hallucis brevis					
flex. digitorum brevis					
quadratus plantae					
abductor digiti minimi					
flex. digiti minimi brevis					
contrahente digitorum pedis					
interossei (dorsal/plantar)	0.8	0.7	0.7	0.1	0.1
lumbricales	0.4	0.1	0.3	<0.1	<0.1
total / % foot segment	1.2g/12.8%	0.8g/10.3%	1.0g/14.7%	0.15g/10.7%	0.15g/7.1%
% hindlimb segment	1.4	1.4	2	2.2	2

TAIL					
weight / % tbw	47.2g/5.0%	43.8g/6.6%	37.3g/6.8%	6.0g/5.6%	6.0g/5.9%
total muscle weight	25.5g	22.2g	18.4g	2.0g	2.4g
% tail segment weight	54	50.7	49.3	33.3	40

APPENDIX E

External Body Measurements

GENERAL MEASUREMENTS:	TBW	TOTAL BODY (L)
Specimen 1 adult (m)	937.6 g	29.5 cm
Specimen 2 adult (f)	661.0 g	28.5 cm
Specimen 3 adult (m)	545.0 g	27.7 cm
Specimen 4 infant (m)	108.1 g	11.5 cm
Specimen 5 infant (m)	102.1 g	10.3 cm

HEAD MEASUREMENTS:	HEAD (L)	HEAD (B)	FACE (B)	FACE (H)
Specimen 1 adult (m)	5.0 cm	4.7 cm	4.2 cm	3.2 cm
Specimen 2 adult (f)	5.7 cm	4.2 cm	3.7 cm	3.7 cm
Specimen 3 adult (m)	5.6 cm	4.1 cm	3.5 cm	3.4 cm
Specimen 4 infant (m)	4.9 cm	3.0 cm	2.5 cm	2.0 cm
Specimen 5 infant (m)	5.0 cm	4.5 cm	3.4 cm	2.9 cm

(L = length; B = breadth; H = height)

TRUNK MEASUREMENTS:	TRUNK (L)	SHOULDER (B)	HIP (B)	TAIL (L)
Specimen 1 adult (m)	19.0 cm	8.7 cm	5.8 cm	37.0 cm
Specimen 2 adult (f)	21.0 cm	5.6 cm	4.0 cm	38.0 cm
Specimen 3 adult (m)	21.5 cm	4.6 cm	4.8 cm	40.2 cm
Specimen 4 infant (m)	7.3 cm	2.9 cm	2.4 cm	19.1 cm
Specimen 5 infant (m)	6.1 cm	3.3 cm	2.1 cm	15.5 cm

FORELIMB MEASUREMENTS:	UPPER ARM (L)	FOREARM (L)	HAND (L)	THUMB (L)	HAND (B)	TOTAL ARM (L)
Specimen 1 adult (m)	6.9 cm	6.5 cm	5.1 cm	1.1 cm	2.2 cm	19.0 cm
Specimen 2 adult (f)	6.8 cm	6.7 cm	5.1 cm	1.5 cm	1.8 cm	18.6 cm
Specimen 3 adult (m)	6.75 cm	7.0 cm	4.5 cm	1.4 cm	1.9 cm	18.25 cm
Specimen 4 infant (m)	3.1 cm	3.4 cm	2.3 cm	0.8 cm	1.2 cm	8.8 cm
Specimen 5 infant (m)	3.8 cm	4.0 cm	2.9 cm	1.2 cm	1.0 cm	10.7 cm

HINDLIMB MEASUREMENTS:	THIGH (L)	LEG (L)	FOOT (L)	FOOT (B)	HALLUX (L)	TOTAL LEG (L)
Specimen 1 adult (m)	8.5 cm	9.1 cm	8.0 cm	2.4 cm	1.6 cm	26.5 cm
Specimen 2 adult (f)	9.0 cm	9.5 cm	8.0 cm	1.7 cm	1.2 cm	25.0 cm
Specimen 3 adult (m)	8.1 cm	9.2 cm	7.7 cm	1.6 cm	1.6 cm	25.0 cm
Specimen 4 infant (m)	3.6 cm	3.8 cm	4.2 cm	1.0 cm	0.8 cm	11.6 cm
Specimen 5 infant (m)	4.2 cm	4.5 cm	4.8 cm	1.2 cm	1.2 cm	13.5 cm

SEGMENT CIRCUMFERENCES:	HEAD	CHEST	UPPER ARM	FOREARM	THIGH	LEG
Specimen 1 adult (m)	17.1 cm	19.5 cm	8.3 cm	7.0 cm	12.2 cm	6.9 cm
Specimen 2 adult (f)	17.0 cm	16.0 cm	5.9 cm	4.8 cm	8.2 cm	5.9 cm
Specimen 3 adult (m)	16.9 cm	13.5 cm	6.0 cm	5.4 cm	8.1 cm	5.5 cm
Specimen 4 infant (m)	12.0 cm	8.6 cm	3.6 cm	3.5 cm	4.6 cm	3.1 cm
Specimen 5 infant (m)	16.2 cm	12.3 cm	4.1 cm	3.8 cm	5.3 cm	3.3 cm

	TAIL
Specimen 1 adult (m)	5.6 cm
Specimen 2 adult (f)	5.7 cm
Specimen 3 adult (m)	5.3 cm
Specimen 4 infant (m)	3.3 cm
Specimen 5 infant (m)	3.1 cm

APPENDIX F

INTERNAL LINEAR MEASUREMENTS

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
			Linear measurements (cm)		
Dentition					
M2L (upper)	0.20	0.20	0.20	0.00	0.00
M2B (upper)	0.35	0.35	0.30	0.00	0.00
M2L (lower)	0.25	0.25	0.25	0.00	0.00
M2B (lower)	0.25	0.25	0.25	0.00	0.00
Cranium/face					
SL	5.00	5.10	5.20	4.10	4.80
SBL	2.35	2.20	2.30	2.20	2.40
BZB	4.10	3.90	3.90	2.20	3.20
Post-cranial					
CL	3.10	2.80	2.70	1.50	1.50
CDL	2.90	2.60	2.50	1.20	1.30
SML	3.50	3.20	3.00	1.50	1.90
HL	7.30	7.00	6.80	3.20	3.60
HDL	6.30	6.40	6.10	2.60	3.00
HMDAP	0.45	0.40	0.40	0.20	0.30
HMDML	0.45	0.40	0.40	0.20	0.30
UL	7.80	7.20	7.00	3.30	4.10
UTL	6.90	6.40	6.10	2.70	3.40
UDL	7.50	6.80	6.70	2.70	3.30
RL(1)	7.10	6.40	6.00	2.80	3.80
RL(2)	6.60	6.10	5.90	2.60	3.50
RDL	6.50	5.90	5.80	2.30	3.10
FL(1)	9.10	9.10	8.50	3.60	4.00

FL(2)	8.70	8.80	8.20	3.60	4.20
FDL	8.30	8.10	7.60	2.80	3.10
FMDAP	0.50	0.50	0.50	0.20	0.30
TL(1)	9.10	8.90	8.20	3.40	4.30
TL(2)	8.80	8.50	7.70	3.20	3.80
TDL	8.20	7.90	7.30	2.60	3.40
OS COXA	3.60	3.70	3.20	1.40	1.90
IB	1.30	1.30	1.20	0.60	0.80
			Bone weights (g)		
CWBW	15.10	20.10	18.80	6.00	7.90
MBW	3.30	2.70	2.90	0.40	1.80
RCLBW	0.40	0.20	0.20	<0.10	<0.10
RSBW	1.50	1.20	0.80	0.30	0.30
RHBW	2.90	2.50	2.30	0.40	0.70
RRBW	1.00	0.90	0.80	0.20	0.40
RUBW	1.40	1.00	1.00	0.20	0.30
RHWBW	1.70	1.90	1.90	0.60	0.80
RFBW	4.40	4.00	3.60	0.80	0.60
RTBW	3.30	3.00	2.50	0.30	0.50
RFIBW	0.60	0.60	0.40	0.10	0.10
RFOABW	3.90	3.00	2.90	0.70	0.90
IBW	5.90	6.40	4.50	0.70	1.00
VBW	44.10	48.20	37.80	7.00	6.40
TLBW	9.90	11.60	10.40	1.80	1.20

APPENDIX G

Dissection techniques

Skinning - dorsal surface

Specimen is placed in a prone "spread eagle" position. Smooth the hair from the neck to the tail. Using a mall probe or teasing needle, create a straight, mid-dorsal line from the nape of the neck to the base of the tail.

Using the scalpel, make an incision of approximately 1 cm long on the adult and only 0.5 cm long on the infant while using the non-cutting hand to apply downward tension on the skin. The incision is only deep enough to penetrate the skin.

Insert the fine pointed scissors (closed) into the incision. Carefully open the scissors to separate the skin from the connective and muscle tissue. Continue this process in all directions until the skin around the incision is free from its attachments.

Insert the closed fine pointed scissors into the incision, keeping in line with the mid-dorsal line that was drawn previously. Lift with enough force to show sufficient separation of the skin from the connective tissues. At this point, insert the open scissors and cut the skin along the mid-dorsal line. Repeat the tissue separation technique along the entire length of the mid-dorsal line.

Once the cut is complete, the skin can be reflected laterally using the blunt dissection technique (the use of the fingers, scalpel handle, or dental pick to separate the tissues). The panniculus carnosus will be seen attached to the skin. It should be removed with the skin tissue.

Continue the skinning process with two transverse mid-dorsal cuts, one just caudal to the forelimb and one just above the pelvic region. Each cut should extend as far ventrally as the position of the specimen will allow.

A transverse cut should be made from the original incision at the nape of the neck ventrally to a point just ventral of the shoulder. Another cut should be made that will circle the proximal end of the humerus.

Moving to the caudal area, a cut should be made from the mid-dorsal cut at the base of the tail along the posterior surface of the thigh. This cut should continue as a circular cut around the proximal end of the thigh.

Skinning of the appendages is not necessary until they are needed for study. The easiest method for removing the skin from the appendages is to make a circular cut around each wrist and ankle. Grasping the skin that has already been loosened at the proximal end of the appendage, pull toward the distal end. If the skin has been properly separated, it will pull away from the muscular tissue. If the skin does not pull free, replace the skin and make a cut along the lateral surface of the appendage separating the tissue as you proceed. Continue the process until the skin is completely removed. It is suggested that the skin of the hands and feet also be removed to facilitate the locating of muscles that extend into those regions.

Skinning of the tail is done using the same technique used on the appendages. A circular incision should be made approximately 1 cm caudal to the base of the tail.

Skinning - ventral surface

Place the specimen in a supine "spread eagle" position. Use the same techniques as outlined for the dorsal surface. Establish a mid-ventral line from the larynx region to the cranial aspect of the pubis. Make a cut along this mid-ventral line.

The transverse cuts from the mid-dorsal incision should be connected to the mid-ventral cut. The skin from each segment should be easily removed independently of each other.

Skinning - head

Extreme care must be taken in the removal of the skin from the head and face region. The transverse incision from the dorsal side should be continued to complete the circular cut around the neck region taking care not to cut the hyoid musculature.

A mid-saggital incision should be made from just above the eyebrows to the posterior base of the neck. Removal of the skin is in a back of the head to the front direction with a slight upward turn in the temporal regions.

Next a transverse incision should be made above the eye orbit extending laterally around the eye. As the incision passes under the eye, the incision should be straightened and then joined under the nostrils. From this point, an incision is made through the upper and lower lips to the mid-ventral incision. Removal of the skin can now be completed.

Removal of individual muscles/organs

Individual muscles listed on the data sheet will be identified by the origin and insertions. Each muscle should be removed in its entirety including the tendon attachments. This allows for identification of the section the muscle will be included with. Upon removal of each muscle or organ system, weighing will take place. After weight has been confirmed by a second weighing, the amount should then be recorded on the data sheet for that particular specimen. All weights should be recorded to the nearest tenth of a gram.

Disposal of materials

No tissue is to be disposed of and will be kept refrigerated until the completion of the project. Once completed, all materials will be placed in biohazard waste "red bags" for disposal. Biohazard waste management will be contacted for the disposal of the bags. All standard University of Arizona disposal practices will be followed.

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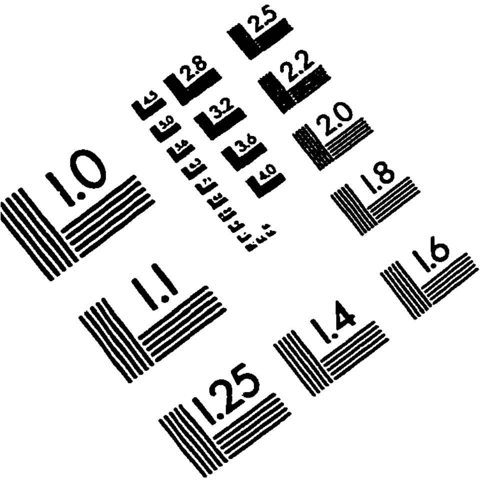
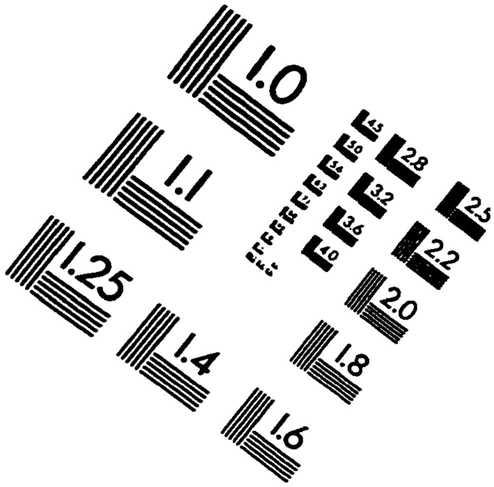
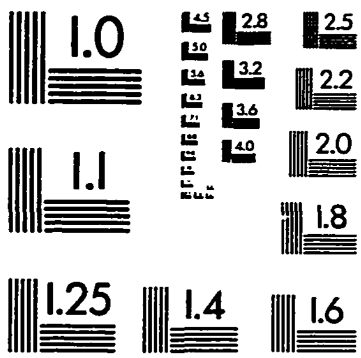
IMAGE EVALUATION TEST TARGET (QA-3)







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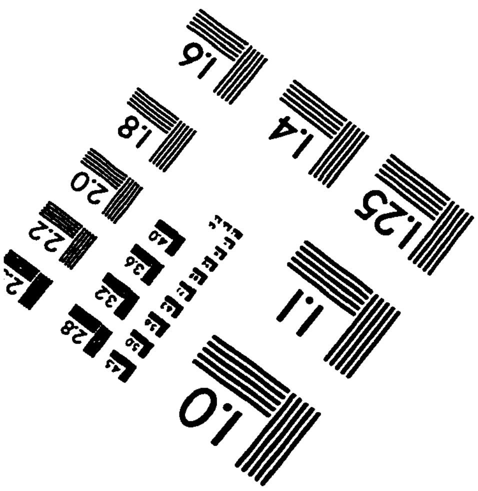

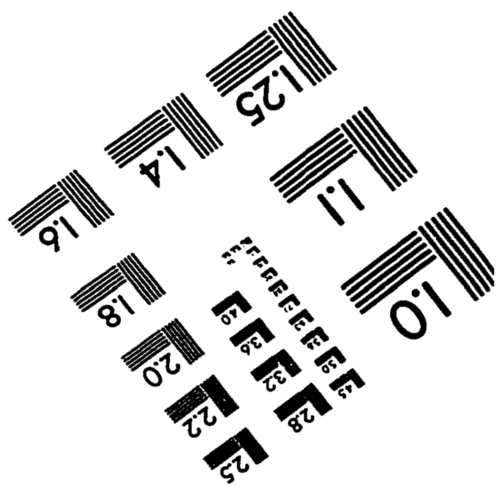

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