



SEX DIFFERENCES

SUMMARIZING MORE THAN A CENTURY
OF SCIENTIFIC RESEARCH

Lee Ellis ♦ Scott Hershberger ♦ Evelyn Field ♦ Scott Wersinger
Sergio Pellis ♦ David Geary ♦ Craig Palmer
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Dedication

This book is dedicated to the tens of thousands of men and women who conducted the studies that are herein cited. Whether these researchers still live or have died, this book is a testament to the efforts they made to reveal sex differences. The book is also a tribute to the scientific method that provides the intellectual arena within which the shroud cloaking these differences is slowly being lifted.

As the research continues to accumulate, the extent to which all sorts of sex differences exist will become ever more evident, and from this knowledge will emerge a better understanding of why. We trust future generations will use this knowledge wisely.

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Preface

In all known cultures, gender is the single most widely used criterion for categorizing people (Martin & Halverson 1981; Maccoby 1988:755; Bussey & Bandura 1999). As Freud (1933:113) observed, “when you meet a human being, the first distinction you make is ‘male’ or ‘female.’” The emphasis we humans put on gender is partly the result of our being sexually reproducing animals. As such, we must be able to distinguish males and females with at least a fair degree of accuracy in order to reproduce successfully. Thus, natural selection has surely honed our sensitivities to maleness and femaleness.

Evolutionary forces may have even contributed to the fact that most human languages contain numerous gender distinctions, including tendencies to give sex-specific names to our children. So compelled are we to identify one another according to sex that we find it awkward to use sex-neutral pronouns when referring to each other, to other animals, and sometimes even to inanimate objects. Perhaps our brains are hardwired to make gender distinctions.

Purpose

In light of the attention that we humans give to gender in everyday life, it is not surprising that many hundreds of new scientific studies on sex differences are published every year. There are also theoretical and practical reasons for this research. In theoretical terms, documenting sex differences contributes to our understanding of many traits and to the sexual differentiation process itself. From a practical standpoint, knowledge of sex differences can lead to ways of reducing, eliminating, or possibly even exaggerating them, should we decide to do so.

With the ever-growing literature on sex differences, a problem is that researchers have become increasingly selective when referencing pertinent evidence. This selectivity runs the risk of both intentional and inadvertent biases. Consequently, a major goal of this book is to minimize biases in literature citations by providing the most complete coverage possible on all aspects of sex differences. Thus, no matter how redundant research findings may be on a particular topic, we have sought to include every relevant published study that could be located.

Readers will discover that numerous findings on sex differences have now been replicated dozens and sometimes even hundreds of times. Even so, for most sex differences, the research is still too sparse to warrant firm generalizations. In other cases, the evidence may be extensive and yet either inconsistent or quite complex. Nevertheless, amidst a multitude of unsettled sex differences are some that can now be regarded as scientifically irrefutable. In some of these latter cases, the research has done little more than confirm the obvious – such as documenting that in all cultures, adult males are taller than adult females. Other instances can be found in which sex differences would probably not have been expected, but are extremely well documented – such as in average weight at birth. For other sex differences, most of the studies will be shown to contradict stereotypes – such as in the case of pain tolerance.

Even when “common sense” is upheld, circumstances change, causing sex differences to vary from one culture to another. Furthermore, natural selection may operate to create sex differences between species as well as within species, and may possibly even impose changes over time. As a result, there is value in continuing to reassess, update, and synthesize what is discovered about how males and females differ. The present book has been assembled to help researchers make ongoing assessments of cultural and species variations in sex differences. With this knowledge, science should be in a better position in the future to offer well-founded explanations for why males and females are so often different.

In essence, the overarching goal of this book is simple but ambitious: *Bring together into a single volume as much scientific information as can be located on how males and females differ (or are the same), and do so in a way that can be easily updated as new studies are published.*

Early in this project, we agreed to make no restrictions regarding the types of traits or even the species of animals to be considered. Even studies of beliefs *about* sex differences (stereotypes, if you will) are included.

Our hope is that readers will find many uses for this distillation of sex difference research. Without claiming that our goal of comprehensiveness was achieved in this initial edition, researchers should be able to use what has been found to enhance understanding of life among sexually reproducing animals. With an emphasis on verifiability, the evidence throughout the book is presented in a way that permits those wishing to cross-check findings to do so.

Sex Difference Controversies

Despite the pervasiveness of scientific research on sex differences, the extent to which males and females actually differ remains a bone of contention, especially when attention is given to human behavior. One reason is the fear that any conclusions drawn may serve to reinforce and perpetuate stereotypes of what “must be” or what “should be.” In an effort to avoid reinforcing sexist social

customs and policies, some researchers have gone out of their way to downplay the differences they discover (Canary & Dindia 1998:3; Crawford & Kaufman 2006:192).

In a related vein, sex difference research continues to spark the centuries-old nature-nurture debate surrounding *causation* (Ward 1992:157). This debate remains fraught with intriguing scientific puzzles, and has become part of what one writer termed “a clash of cultures, of ideologies, and of politics” (Pool 1993:198). This means that the interests of some researchers in sex differences are being driven more by political agendas than by objective curiosity. As a result, emotional feelings and even moral convictions sometimes shade how findings are reported and interpreted.

This book largely avoids all explanatory aspects of sex difference research. It does, however, provide a platform on which future debates over etiology can be more objectively waged. Concerted efforts were made to avoid mistakes, although shortcomings in this regard are inevitable. Therefore, if any errors or omissions regarding the evidence contained within this book are identified, a simple internet procedure is presented later in this preface for correcting and adding to future editions.

The Male-Female Language Controversy

Serious, and even heated, debates have erupted over the use of terms such as *sex* and *gender* for describing male-female differences, especially regarding behavior. Since the 1970s (Unger 1979:1086), a common proposal has been to refer to the genetic/physiological aspects of males and females as *sex* and to use *gender* to refer to the learned/sociocultural aspects (e.g., Kandrack et al. 1991:580; Fausto-Sterling 1993; PL Walker & Cook 1998; Sebrant 1998; Reeder 2003; Aylor & Dainton 2004; Lewine 2004:755). We believe that attempting to make such a distinction is misguided for three reasons.

First and foremost, distinguishing *sex* from *gender* assumes that scientists *know* what aspects of maleness and femaleness are biological and what aspects are sociocultural. In fact, scientists still do not know what is responsible for most sex differences, especially when it comes to behavior (Sagrestano et al. 2006:382). The causes of sex differences will be determined empirically, not intuitively or from today’s accepted wisdom. It already seems a safe bet that most differences between human sex differences will be found to result from the interaction of both biological *and* learned sociocultural factors. If so, those who advocate distinguishing sex from gender on the basis of what causes average male-female differences will have to use some sort of amalgamated term such as “sexder” to characterize most differences.

Second, if human males and females have both a sex and a gender, what about other animals? This question is particularly pertinent to this book because quite a number of tables will document traits in which the same basic male-female differences exist across a wide spectrum of species, not just among humans.

Third, if humans (and other animals) have both a sex and a gender, is gender a dichotomous variable (male-female) or is it continuous (masculine-androgynous-feminine)? Answers to this question continue to differ (see Hyde 2005). If, as some have suggested, gender is continuous and not dichotomous (e.g., Reeder 2003), logic would compel one to no longer use the word *gender* to refer to males or females (Deaux 1985). In this regard, several tables throughout this book will document how males and females are generally either male-typical/masculine or female-typical/feminine regarding various behavior patterns.

To put our perspective on the sex-versus-gender controversy in more succinct terms, as long as the possible values for the variable of sex or gender are identical (i.e., male, female), one is effectively dealing with a single variable no matter how many different names are given to it (e.g., sex, gender, male-female). Thus, we join others (e.g., LA Gilbert 1992:385; Nasser et al. 2002) in believing that it is best to consider the terms *sex* and *gender* as synonymous in the context of distinguishing males and females. Consequently, throughout this book, *gender*, *sex*, and *male-female* will all be used interchangeably. Readers wishing to maintain some sort of distinction between sex and gender may simply substitute the term *male-female* each time they encounter the words *sex* or *gender*.

History of the Project

The idea that it might be possible to compile a comprehensive book on gender differences came to the first-listed author in 1997. Over the ensuing months, he contacted other researchers known to be interested in sex differences to see if they would join in the project. Several declined, but within a year, enough had agreed to become involved to make the project seem feasible. With the indispensable help of dozens of student workers over the ensuing years, the book gradually took shape.

During the first two years, nearly all of the work was confined to reading articles and books containing reports of gender differences and recording the nature of these differences. By the third and fourth years, the thousands of citations that had accumulated to that point slowly began to be organized into computer-generated tables. In 2002, as the collection of new citations continued, increasing efforts turned to organizing what was by then over a thousand tables into chapters, and by 2003 we started writing narratives around each table. Since that time, we have continued to incorporate thousands of new citations, add hundreds of additional tables, and refine the narratives surrounding each table.

In the summer of 2005, a major setback befell our efforts to complete the project. The main computer containing the latest version of the book was stolen, resulting in the loss of approximately 150 hours of work. Fortunately, paper copies of most of the citations that had been entered had been retained, allowing us to eventually recover and reenter about 90% of the lost information.

The Book's Main Parameters

As already noted, the goal of this book was to compile and summarize all of the scientific evidence surrounding gender differences. In this first edition, over 18,000 studies are cited (many of which are cited more than once). Thus, within the 1,920 tables appear approximately 30,000 citations. There is no way of knowing how many studies are “out there” remaining to be included, but our estimate is that it is at least double the number contained in this edition. A more tangible indicator of the massiveness of the sex difference literature involves noting that over fifty newly published studies pertaining to these differences are appearing in the scientific literature each week (as discussed below).

In addition to attempting to be as comprehensive as possible, we settled upon two additional features for the book. First, it should be expandable in the sense that information can be updated in future editions. To accomplish this, we have devoted a separate table to every sex difference that could be located. Second, we wanted the book to be entirely verifiable and correctable. In this regard, information appears later in this preface for readers who detect any errors or are aware of any additional citations for inclusion in future editions.

Types of Sex Differences

Nearly all of the sex differences revealed in this book are of four types: average differences, differences in proportions, differences in variability, and trends in differences. Average differences are determined by adding the total scores for a variable divided by the total number of males and the total number of females. Proportional sex differences are usually expressed in percentage terms. Regarding sex differences in trait variability, researchers have sought to determine if the standard deviation for a trait is significantly greater for one sex than for the other. A few studies also pertain to trends in sex differences.

Characterizing Sex Differences

In nearly all of the tables, sex differences are described in terms of the gender exhibiting each trait to the greatest degree, regardless of the trait's desirability. The designation of “more” in some cases was arbitrary. For example, in the case of life expectancy, it could have been described in terms of which sex died earlier or which one lived longer (we choose to use the latter).

The extent of sex differences is generally not indicated (e.g., whether one sex exhibits a trait to twice the extent of the other). Only whether the difference was considered statistically significant or not was recorded. In this regard, it should be noted that most sex differences are relatively small (Canary & Hause 1993), and, for this reason, it should not be surprising that, even when there are real differences, they will not always be statistically significant.

Locating Relevant Publications

Almost every conceivable method for obtaining publications on gender differences was utilized, including leads from word-of-mouth, previously published reviews, email and internet searches, interlibrary loans, and simply thumbing through journals. Nevertheless, the most extensively used source by far involved systematically searching through weekly issues of *Current Contents* for both the *Life Sciences* and the *Behavioral and Social Sciences* since the early 1990s. (Profound gratitude is extended to Dr. Eugene Garfield of the Institute for Scientific Information for developing this resource and providing access to it throughout the course of this project.)

Searching *Current Contents* was done electronically by flagging all references containing the words *sex* or *gender*. Copies of nearly all of the flagged publications were then sought either directly from their first authors or from library sources. In this way, at least 50 new articles were identified every week since the mid 1990s (in the last few years, the numbers have crept upward toward 70 per week).

Reflecting the cumulative nature of the scientific method, nearly all of the contemporary articles with information about gender differences also cite prior relevant publications. If everything appeared clear and credible in these secondary citations, they too were included in the book's tables without reading them first-hand. When doubts arose concerning the accuracy of a secondary citation, copies of the relevant primary sources were obtained for verification.

Organization of the Book

The book's findings have been organized into the following twelve primary chapters:

- Chapter 1 – Basic Biological Factors
- Chapter 2 – The Brain and Biochemistry
- Chapter 3 – Health and Illness Factors
- Chapter 4 – Perceptual, Motor, and Emotional Factors
- Chapter 5 – Intellectual, Cognitive, Self-Concept, and Mental Health/Illness Factors
- Chapter 6 – Preferences, Interests, Attitudes, Beliefs, and Intentions
- Chapter 7 – Drug-, Therapeutic-, and Stress-Related Responses
- Chapter 8 – Personality and General Behavior

- Chapter 9 – Social Behavior
- Chapter 10 – Consuming and Individual-Institutional Interactions
- Chapter 11 – Stratification and Work-Related Behavior
- Chapter 12 – Attitudes and Actions toward Others in Relationship to Their Gender

A final “grand summary” chapter (Chapter 13) provides a condensation of all of the findings from the tables in the initial twelve chapters that contained at least ten findings from studies of human subjects. The special statistical treatment given to these tables is described near the end of this preface.

Structure of the Tables

All studies pertaining to gender differences are presented within tables, even if just one relevant study was located. Accompanying each table is a narrative that describes the nature of each variable (unless it is well known) and then characterizes the evidence provided by the table (along with any noteworthy qualifications).

Most of the tables have the same overall format. The three options with respect to gender differences – *males more*, *no significant difference*, and *females more* – are listed along the left side. Across the top, the following age categories are identified: *infant* (in humans, under one year of age), *toddler* (in humans, 1 to 2 years of age), *early childhood* (in humans, 3 to 5 years of age), *childhood* (in humans, 6 to 12 years of age), *adolescent* (in humans, 13 to 18 years of age), *adult* (in humans, 19 years and older), and *multiple age categories*. In this latter case, the study’s sample either encompassed both adolescent and adult subjects or a qualifier following the citation specifies the age groups involved.

To enable readers to look for possible cultural variations in the research findings, the country within which each study was conducted is indicated. When special subpopulations were sampled, ethnic and tribal identifiers appear in parentheses immediately following the relevant citation.

Countries are organized with regard to the region of the world in which they are located. The regional categories used were as follows: *Africa*, *Asia*, *Europe*, *Latin America*, *Middle East*, *North America*, and *Oceania* (the latter primarily encompassing islands in the Pacific and Indian Oceans). In some cases, islands were subsumed under nearby continents. For example, Britain and Iceland were listed under *Europe*, and both Japan and Taiwan were considered part of *Asia*. All of the American countries and islands of the Caribbean in which Spanish or Portuguese are the dominant languages were subsumed under *Latin America*. In the case of Hawaii, it was considered part of *Oceania* when information was available for it specifically; otherwise its data were treated simply as part of the *United States*.

While most of the studies were based on research involving human subjects, about 10% are derived from observing other animals. When nonhumans were the subjects of study, reasonable judgments were made to indicate the age of the animals sampled in terms of their human equivalencies. Citations to studies of nonhuman animals are included in the tables according to species (or species type) rather than according to the country in which they lived. The closer the species is to humans in phylogenetic terms, the more specific was the species classification. For example, chimpanzees, gorillas, orangutans, and gibbons were subsumed under *ape*, while all species of monkeys and prosimians were categorized as *primate other than ape*.

What Constitutes Published Research

The basic criterion used for including research findings in this book was that the findings must have been published. No restrictions were made in terms of the language in which the report was written. Fortunately, in this regard, nearly all scientific research reports are either published in English or at least contain an English language abstract, and English is the native language of all but two of this book’s authors.

The criteria used to consider a study as having been *published* included their having appeared in the form of a journal article and book. Dissertations were also considered “published,” but master’s theses and conference papers were not unless they appeared in a formally bound proceedings book generally available through library sources. Material that was available only on the internet without evidence of paper copies being available through public library sources was not considered “published.”

Comprehensiveness and Inconsistencies in the Findings

Most of the tables are either highly consistent or at least fairly consistent in indicating a specific gender difference. Nevertheless, scattered throughout the book are citations to studies whose findings are not consistent. Some of these exceptional findings can be dismissed as chance events attributable to small sample sizes and/or to the fact that many gender differences themselves are *in fact* so minuscule as to yield inconsistent results from one study to the next. Readers should bear in mind that the concept of *statistical significance* used in nearly all of the studies cited in this book allows for a 5% chance of the finding being a statistical fluke. Other reasons for inconsistencies within tables are as follows:

First, some researchers may have made errors in their mathematical notations or calculations. Such events are inevitable given that science is, alas, a human enterprise.

Second, much of the data on human sex differences derive from self-reports by ordinary people. Questions are sometimes phrased in ways that are misinterpreted, or subjects purposely misreported due to embarrassment or to a desire not to offend or disappoint those seeking the information.

Third, few samples used in research on human behavior and health are completely representative of a national population (Sher & Trull 1996; Hartung & Widiger 1998). This means that two studies of the same sex differences might be carried out in the same country, but one study might be based on interviews of college students in the United States while the other was derived from mailed questionnaires completed by home residents. If these two studies happened to reach opposite conclusions regarding any sex differences, both could be correct for their particular split-populations.

Fourth, not all studies will be in agreement because the answers to some questions about gender differences may vary according to the culture, time frame, or species being studied. When these types of variations seem to be involved, the narratives surrounding tables allude to such possibilities.

Fifth, the authors and other contributors to the present book may have erred in reading studies and/or in transcribing findings into the most pertinent table. If readers detect any questionable entries, they are encouraged to consult the original report to confirm their suspicions. If confirmed, please visit the website for revisions and updates to this book and provide the necessary corrective information. The location for this website is provided at the end of this preface.

Finally, to an unknown degree, researchers may be more likely to publish findings in which significant sex differences are found than those in which no such differences are found. If so, many of the tables in this book may provide at least a slightly inflated estimate of the actual degree to which males and females differ rather than an underestimate.

The Book's Analytic Character

Does the present book constitute a meta-analysis? A meta-analysis is sometimes defined as “a study of studies,” and, in this sense, this book is unquestionably a meta-analysis. However, in a narrower sense, a meta-analysis involves converting the findings from all relevant studies to a common statistic and adjusting for variations in sample size. In this sense, our book is not a meta-analysis.

Perhaps the best description for the approach taken by the present book is that it is a *type* of meta-analysis that uses a *ballot-box* or vote-counting method rather than statistical conversion to a common statistic (Hedges & Olkin 1985:47; Jarvis 1992:1252). What qualifies a study to cast a vote is the fact that it was published as an empirical investigation. Each “vote” can be for one of three outcomes: *males more*, *no significant difference*, or *females more*. Rather than attempting to adjust each finding according to the sample size, each finding carries the same weight as all others. Nevertheless, in some of the narratives surrounding a table, comments are made to suggest that some qualitative assessments are in order.

There were three reasons the ballot-box approach was adopted instead of the more conventional (effect size) type of meta-analysis. First, the ballot-box approach is easier in the sense that one does not have to do anything more than determine if a particular sex difference was statistically significant in each individual study. No adjustments had to be made for variations in a study's sample size or other measures of statistical power. Second, a conventional meta-analysis does not lend itself well to accommodating variations over time, by age, or from one culture to another. This is because a conventional meta-analysis involves pooling results from all of the available studies into a single statistic. Detecting temporal, age-related, and cultural variations was something we considered important to preserve because one of the hoped-for outcomes of this book is to begin revealing the extent to which sex differences have cross-cultural variability. Even variations in sex differences across species can be detected using the present book's methodology. Third, when compared to the more conventional type of meta-analysis, the vote-counting version lends itself to being much more easily updated as additional studies are reported.

Statistical Significance

Despite its limitations, the concept of *statistical significance* has been, and continues to be, a valuable tool for scientists who must base almost all of their research findings on samples. Throughout this book, we have relied on whatever statistical significance test a researcher used in a particular study (unless specifically indicated otherwise). In the vast majority of cases, this means that the maximum degree of sampling error allowed was .05. Nearly all of the studies cited assumed the more conservative two-tailed version of whatever statistical test that was used. Where this was not the case, and the less conservative one-tailed test would have made the differences between significance and non-significance, both results are indicated within the relevant table.

Citation Style

Slight variations on the widely used American Psychological Association (APA) style of citation are employed throughout this book. The features that deviate from the APA style are as follows:

To help reduce confusing the enormous number of references, a seemingly common last name for a citation's lead author is preceded with the author's initials (without periods or spaces between them). Thus, an article by *Smith* would be preceded with his/her initials, such as *AW Smith*.

To keep citations as brief as possible, when an article, chapter, or book had three or more authors, it was simply referred to by the first author's last name (plus initials, if the name was common) and the notation *et al.* followed by the year of publication. No commas are used to separate authors and the year their work was published, although, in many instances, a page number is cited following the year of publication in order to assist readers wishing to verify a particular finding, especially in the case of lengthy publications.

Special Notations and Qualifiers

Few arbitrary symbols and notations are used anywhere in this book. The most common special notation employed in the tables is an asterisk (*). This symbol signifies that a particular study is cited more than once within that particular table. The two main reasons for multiple citations to a study within a table are these: First, one study may have sampled two or more age groupings (as specified in the tables), and so the nature of the gender difference is indicated for each age category sampled. Second, a study might report results for two or more different countries or two or more different ethnic groups. For each country or group, the nature of the gender differences for the trait in question will be indicated following the asterisk.

Also appearing frequently after table citations are what are called *qualifiers*. A qualifier is a word or phrase that serves to delimit the nature of the sample used in a particular study. For example, if the subjects of a study were college students (which we considered adults), the word "college" appears after the study's citation. If persons over 60 were predominantly sampled, the word "elderly" is noted following the study's citation. Similarly, if a study's subjects were all in the range of 5 or 6 years of age, they would be classified under "childhood," but with a qualifier "young." Many other qualifiers appear after particular citations to provide information about the type of methodology used to obtain the data, such as indicating that a particular study was based on self-reports as opposed to a clinical diagnosis.

Sex differences may vary not only from one society to another, but within societies as well, especially over extended periods of time. In this regard, one can note that the vast majority of studies (~ 95%) are published within a decade after the data for the study were collected. However, there are exceptions, such as when centuries-old church records are used to reveal marriage patterns and birth rates. Therefore, to give some time-dimension to the studies reviewed besides those associated with the year of publication a special notation is made following any study based on data collected prior to the 20th Centuries. Thus, if 19th *Century* appears as a qualifier following a particular study, data for that study were obtained sometime in the 1800s even if the study itself was published much more recently.

Studies in which Statistical Significance Was Not Reported

In a few studies, such as population-wide studies of an entire country, statistical significance was not reported. The following guidelines were used to assign such a study's results into one of the three outcome options: If more than five percentage points separate one gender from the other, a significance gender difference was declared; if the percentage difference was less than five, the finding was considered non-significant. Fewer than a dozen studies are cited throughout this book for which this note is relevant.

Assessing Human Universals

For each table in which at least 10 findings were located pertaining to humans, an indicator of the universality of the trait is presented. This is called the *Consistency Index (CI)*. The formula used to derive the CI was as follows:

$$CI = TSD - (NSD + 2CSD)/TSD$$

Where **TSD** is the total number sex difference findings that were located,

NSD is the number of findings of no significant sex difference, and

CSD is the number of findings of a sex difference contrary to the majority.

Three simple hypothetical examples will illustrate how a CI was derived. For the first example, assume that 40 studies were conducted concerning a possible sex difference in Variable V and that all of these studies concluded that females exhibited Variable V to a greater extent than did males. In this case, the CI would be $40 - (0 + 0)$ divided by 40, yielding $CI_{(40)} = 100$.

In the second hypothetical example, assume that 40 studies were located bearing on Characteristic C, and that 38 of these studies found males scoring significantly higher than chance probability, while the remaining 2 studies found no significant gender difference. For Characteristic C, the CI score would be $40 - (2 + 0)$ divided by 40, yielding $CI_{(40)} = 95$.

The third example will be slightly more complicated. Assume once again that 40 studies were located concerning gender differences in Trait T, and that 34 of these studies found females exhibiting this trait to a greater than chance degree. Of the remaining studies, 4 found no significant gender difference, and 3 studies actually found males exhibiting Trait T to a significantly greater extent than females. Under these circumstances, the CI score would be calculated as follows: $40 - (4 + 6)$ divided by 40, yielding $CI_{(40)} = .75$.

While the actual scores for each consistency index will be presented, they will be grouped into six categorical levels for summary purposes. These summary categories are as follows:

Categorical Descriptors	CI scores
Essentially a certain sex difference	100% consistency
A well established sex difference	95-99% consistency
An established sex difference	85-94% consistency
A probable sex difference	70-84% consistency
A possible sex difference	50-69% consistency
An un-established sex difference	Below 50% consistency

As mentioned earlier, consistency index scores are only presented for tables in which at least 10 findings involving humans were located. In some cases, if at least 10 findings were located for more than one age category, then separate CI scores were calculated for each age grouping. The reasons for doing so will be explained more in Chapter 13.

A closing comment to make regarding the derivation of consistency index scores is that several studies report more than one finding pertinent to a given table. (As mentioned earlier, these studies are marked with an asterisk.) For instance, a study might have sampled by school age children and adolescents, and in both cases found females exhibited a particular trait more than males. This study would be counted twice in deriving the consistency index.

Following each CI score is a second number, termed a *DI* (for *Diversity Index*). The DI is derived by counting the number of countries, cultures, and centuries for which a particular sex difference was reported. A few studies did not report the exact number of countries/cultures (such as studies whose samples came from “several industrialized countries” or “multiple cultures”). In these cases, one or more plus signs (+) appear after the DI value. If studies of a particular country involved not only the 20th or 21st Century, but also an earlier century, that country was counted twice (as though it were another country) in deriving the DI. (For studies of nonhumans, the DI was derived by counting the number of species sampled in a particular table.)

To illustrate the DI, assume that 40 findings were used to derive a particular CI. Further assume that 30 of these findings were based on samples drawn from just one country (the United States, for example), and that the remaining 10 findings came from two other countries. This would mean that the DI would be 3 unless one or more of the studies had been carried out in a century prior to 1900. Assume for instance that one of the studies from the country with 30 studies had been based on a population surveyed in the 1830s while all of the remaining studies were based on 20th or 21st Century samples. Accordingly, the final DI for that particular table would be 4.

In summary, two indices of *universality* are used in Chapter 13 for every table in which at least 10 findings of human sex differences were located: a consistency index and a diversity index. The first number (the CI) indicates how consistent the reports of gender differences have been (along with the actual number of studies involved), while the second index (the DI) provides a rough estimate of the extent to which the samples were derived from numerous cultures and time frames (or from different species in the case of non-humans). The higher each of these two numbers, the stronger would be the inference that a particular sex difference is universal. The tables containing these scores will be given special attention in this book’s final chapter.

We wish to emphasize that all CIs and DIs reported in this book should be considered conservative and imperfect numeric estimates. They are conservative in the sense that there is bound to be considerably more societal and cultural diversity than that revealed by merely counting the number of societies/cultures and centuries during which studies were conducted. Regarding imperfections embedded in these two indexes, they include measurement and sampling errors contained within each study cited, our failures to locate all of the relevant research, and our incorrectly interpreting (or qualifying) reported findings.

Corrections and Future Editions of This Book

Despite our *goal* of including citations and references to every scientific study ever published on sex differences, we have no illusion that such a goal was accomplished in this book’s initial edition (although 30,000 citations to 18,000 studies is certainly a start). Readers are invited to assist in improving future editions by providing information on any errors or omissions that they identify. Comments pertaining to these errors or omissions may be easily posted at the following web address: <http://www.psypress.com/sexdifferences>. Also, if any significant errors in the first edition are found, we will post the corrections at this same web location.

Chapter 1

BASIC BIOLOGICAL FACTORS

Biological variables are all those having to do with life. This would include an animal's anatomy, physiology, and even how it thinks and behaves. Thus, in the broadest sense of the word, this entire book is about the biology of sex differences. However, in a narrower sense, variables having to do with behavior, emotions, cognition and the like are conceptualized as being outside the realm of biology, so that this book extends to such non-biological topics as thought, feelings, and behavior.

In this initial chapter, findings pertaining to some of the most basic biological factors of all will be examined. Studies of such things as sex ratios at birth, birth weights, adult weights, sizes of various bodily organs, and bodily functioning will receive attention.

Omitted from this chapter are the variables of behavior, emotions, and cognition. Also, because of their complexity and extensiveness, other biological factors – such as the brain, biochemistry, health/illness, and physiological responses to drugs and to stress – will be covered in later chapters.

1.1

THE BEGINNINGS AND MAJOR TRANSITIONS OF LIFE

This initial section is concerned with some of the most fundamental aspects of life in sexually reproducing animals, such as the proportion of species members who are of each sex. Also considered are the rates at which males and females mature.

1.1.1. Sex Ratios

A population's sex ratio refers to the proportion of each sex at a given point in time or stage in development. Sex ratios are of interest to biologists because these ratios vary considerably from species to species, a fact that continues to beg for evolutionary as well as physiological explanations. Even sex ratios in species of plants – not a topic of review in this book – have been the focus of scientific inquiry (DR Taylor 1999).

The sex ratio at or near to the time of conception is considered the *primary sex ratio* while the ratio at birth (or hatching) is termed the *secondary sex ratio*. Statistics on sex ratios any time following birth are usually referred to as *tertiary sex ratios*. As this section shows, most of the research involving sex ratios has to do with those observed at the time of birth.

1.1.1.1. Sex Ratio During Gestation (Primary Sex Ratio)

Research regarding the *primary sex ratios* is largely confined to the study of aborted and miscarried human fetuses. As shown in Table 1.1.1.1, these studies indicate that males are conceived at substantially higher rates than females. The degree to which male conceptions outnumber female conceptions has been rated to be as high as 160 to 100 in humans (Moore & Persaud 1998). By the end of the first trimester, the sex ratio in humans appears to be closer to 130 to 100. Among non-human species for which data are available, the sex ratio also favors males, with ratios of 180 to 100 for hamsters and 122 to 100 for rabbits. The only animal for which no significant male-female differences were found involved a species of fish.

Table 1.1.1.1. Sex ratio during gestation (primary sex ratio).

Nature of Any Difference	At or Shortly After Conception	Later in Gestation
More males	ASIA Japan: Mizuno 2000 EUROPE Britain: FA Woods 1939 (royal families); Hytten 1982; <i>Germany:</i> Auerbach 1912 NORTH AMERICA United States: Potter 1940; Kukharenko 1970 (151/100 in second month); MM Mcmillen 1979; Hassold et al. 1983; Byrne & Warburton 1987; KL Moore & Persaud 1998 MAMMAL Rabbit: Shaver & Carr 1969 (122/100) RODENT Golden Hamster: Sundell 1962 (160/100)	NORTH AMERICA United States: Kukharenko 1970 (end of 1 st trimester)
No signif difference	RODENT Gerbil: MM Clark et al. 1990 (sex of fetuses in the uterine horn)	FISH Barbel: Baras 1992
More females		

1.1.1.2. Sex Difference in Fetuses Aborted

A limited number of studies have identified the sex of induced aborted fetuses (not including miscarriages). As shown in Table 1.1.1.2, findings have been inconsistent. This may be at least partly due to two countervailing factors. First, many more males are conceived than females (roughly 130 to 100, as noted in the above table on humans); thus, by chance they are more likely to be aborted. Second, in some countries, female fetuses are selectively aborted.

Table 1.1.1.2. Sex difference in fetuses aborted.

Nature of Any Difference	Citations
More males	ASIA Japan: Yamamoto et al. 1977; Ohama 1978 NORTH AMERICA United States: Kukharenko 1970 (end of 1 st trimester); Byrne & Warburton 1987
No signif difference	
More females	ASIA China: Junhong 2001; <i>India:</i> Patel 1989; <i>Japan:</i> Kajii et al. 1978; <i>South Korea:</i> Park & Cho 1995

1.1.1.3a. Sex Ratio at Birth (Secondary Sex Ratio) for Humans in North America

An enormous number of studies have been published regarding *secondary sex ratios*. Therefore, the results are presented in three split-tables, one for humans in North America, one for humans elsewhere in the world, and the other for non-humans. Split-Table 1.1.1.3a shows that nearly all studies of humans in the North America have found that the number of males born significantly exceeds the number of females born. The most typical ratio is in the vicinity of 103-106 males for every 100 females.

Split-Table 1.1.1.3a. Sex ratio at birth (secondary sex ratio) for humans in North America.

Nature of Any Difference	Citations
Males more prevalent	NORTH AMERICA Canada: BB Allan et al. 1997; Jongbloet 2004:772; <i>United States:</i> Parkes 1926; Crew 1927; Schultz 1928; H Bakwin 1929; S Winston 1931; Ciocco 1938c; ME Bernstein 1948:184; Novitski 1953; Slatis 1953; ME Bernstein 1954; MacMahon & Pugh 1954:286; Fancher 1956:318 (upper class); Novitski & Kimball 1958; Lyster 1971; Teitelbaum & Mantel 1971; JD Erickson 1976; Curtsinger et al. 1983; BB Little et al. 1987 (fathers who were pilots & astronauts); US Bureau of the Census 1988; Mackey 1993:192; Milham 1993:830; WH James 1995:244; Mittwoch 1996; Guest et al. 1998:27; Marcus et al. 1998 (Blacks); Fuentes-Afflick et al. 1999:149; Nicolich et al. 2000; L Ellis & Blanchard 2001:550; Grech et al. 2002:1011*; WH James 2003 (Blacks); JM Mills et al. 2003; Norberg 2004
No signif difference	NORTH AMERICA United States: Heron 1906
Females more prevalent	NORTH AMERICA Canada: Mackenzie et al. 2005 (Aamjiwnaang community, near large petrochemical plants)

1.1.1.3b. Sex Ratio at Birth (Secondary Sex Ratio) for Humans in Countries Outside North America

As with humans born in North America, studies elsewhere in the world have found significantly more males than females born (Table 1.1.1.3b).

Split-Table 1.1.1.3b. Sex ratio at birth (secondary sex ratio) for humans in countries outside North America.

Nature of Any Difference	Citations
Males more prevalent	<p>AFRICA <i>Ethiopia</i>: MA Gibson & Mace 2003 (rural); <i>Nigeria</i>: Ayeni 1975; <i>South Africa</i>: N Howell 1979:247 (!Kung tribe)</p> <p>ASIA <i>China</i>: Coale 1984:28; Wu 1988; TH Hull 1990; Coale 1991; Johansson & Nygren 1991; Zeng et al. 1993; Tomlinson 1994; Xu et al. 1994; BA Anderson & Silver 1995; Ren 1995; N Riley 1996; Li et al. 2000; Lavelly 2001; Leung et al. 2002; Secondi 2002:220; Klasen & Wink 2003; Lai 2005:317; <i>India</i>: Visaria 1971; Visaria 1972; Kumar 1989; TH Hull 1990; Kanitkar 1991; Kundu & Sahu 1991; Dyson 1994; Srinivasan 1994; Das Gupta & Bhat 1997; P Mayer 1999; Peng & Huang 1999; P Griffiths et al. 2000; Bhat 2002; Guillot 2002; Bhargava 2003:228; Retherford & Roy 2003; Jayaraj & Subramanian 2004:107; <i>Japan</i>: de Jastrzebski 1919*; WT Russel 1936; Imaizumi & Murata 1981; Fukuda et al. 1998; Mizuno 2000; Sakamoto et al. 2001:94*; <i>Korea</i>: WT Russell 1936; Kang & Cho 1959:189; Visaria 1967*; CB Park & Cho 1995; <i>Pakistan</i>: Visaria 1967*; <i>Russia</i>: Antonov 1947; <i>Taiwan</i>: CY Yang et al. 2000 (high petroleum polluted area); <i>Vietnam</i>: Goodkind 1995; Belanger et al. 2003</p> <p>EUROPE <i>Austria</i>: de Jastrzebski 1919* (Jews); Grech et al. 2002:1011*; <i>Belgium</i>: Grech et al. 2002:1011*; <i>Britain</i>: Graunt 1676 (17th Century); Darwin 1874* (19th Century); Punnett 1904; Tidswell 1912; SJ Holmes & Goff 1923:236*; FA Woods 1939* (royal families); WJ Martin 1942; Beiles 1974 (19th Century); WH James & Rostron 1985; Grech et al. 2002:1011*; Leung et al. 2002 (preconception smoking parents); Heron & Ness 2004 (preconception smoking parents); <i>Bulgaria</i>: Grech et al. 2002:1011*; <i>Croatia</i>: Polasek et al. 2005 (during 1991 – war); <i>Czech Republic</i>: Grech et al. 2002:1011*; <i>Denmark</i>: Bromen & Jockel 1996; Moller 1996 (1851-1995); Moller 1999; Hansen 1999; Grech et al. 2002:1011*; Obel et al. 2003 (preconception smoking parents); <i>Finland</i>: Vartiainen et al. 1999; Lummaa et al. 1998; Huopaniemi et al. 1999; S Scott & Duncan 1999 (17th & 18th Centuries); Vartiainen et al. 1999; Grech et al. 2002:1011*; <i>France</i>: Darwin 1874 (19th Century)*; Grech et al. 2002:1011*; <i>Germany</i>: Matzdorff 1981:640; van den Broeck 1997; Lerchl 1998; Lerchl 1999; Grech et al. 2002:1011*; Catalano 2003; Kemkes-Grottenhaler 2004 (17th & 18th Century); <i>Greece</i>: Grech et al. 2002:1011*; <i>Hungary</i>: Da Jastrzebski 1919; Grech et al. 2002:1011*; <i>Iceland</i>: Grech et al. 2002:1011*; <i>Ireland</i>: JB Moynihan & Breathnach 1999; Grech et al. 2002:1011*; <i>Italy</i>: Savorgnan 1933; Ulizzi & Zonta 1993; Ulizzi & Zonta 1995; Astolfi & Zonta 1999 (urban); Grech et al. 2002:1011*; Cagnacci et al. 2004; <i>Luxembourg</i>: Grech et al. 2002:1011*; <i>Malta</i>: Grech et al. 2002:1011*; <i>Netherlands</i>: Z Stein & Susser 1975; van den Broeck 1997; van der Pal-de Bruin et al. 1997; Grech et al. 2002:1011*; <i>Norway</i>: Grech et al. 2002:1011*; <i>Poland</i>: Grech et al. 2002:1011*; <i>Portugal</i>: Grech et al. 2002:1011*; <i>Prussia</i>: von Fircks 1889 (19th Century); <i>Romania</i>: Grech et al. 2002:1011*; <i>Scotland</i>: GG Smith 2000; <i>Slovenia</i>: Zorn et al. 2002; <i>Spain</i>: Grech et al. 2002:1011*; <i>Sweden</i>: SJ Holmes & Goff 1923:247*; Grech et al. 2002:1011*; JM Mills et al. 2003:1244; Catalano & Bruckner 2004:539; <i>Switzerland</i>: Grech et al. 2002:1011*; <i>Multiple European Countries</i>: Gini 1908; Savorgnan 1933; WT Russell 1936; Grech et al. 2000; Martuzzi et al. 2001; Stini 2003:25 <i>Yugoslavia</i>: Polasek 2006 (1991 – 1995 during war in former Yugoslavia)</p> <p>LATIN AMERICA <i>Cuba</i>: Heape 1908a* (Whites); <i>Ecuador</i>: F Baker 1969; <i>Mexico</i>: Grech et al. 2002:1011*; <i>Venezuela</i>: Chacon-Puiguanu & Jaffe 1996:265; <i>Multiple Countries</i>: Feitosa & Krieger 1992; Feitosa & Krieger 1993</p> <p>MIDDLE EAST <i>Iran</i>: Ansari-Lari et al. 2002* (general population); Saadat et al. 2002* (near natural gas leakage); <i>Israel</i>: Riis 1999:37</p> <p>OCEANIA <i>Australia</i>: Australian Bureau of Statistics 1997; T Hurst et al. 1997; <i>Micronesia</i>: Krzywicki 1934:230; EE Hunt et al. 1965; M Marshall 1975; Nason 1975; Federated States of Micronesia 1988:17; Brewis 1992; Brewis 1993; JH Underwood 1993; JH Underwood 1995</p> <p><i>Japan</i>: Fukuda et al. 2002* (among nonsmoking parents)</p> <p>INTERNATIONAL <i>Multiple Industrial Countries</i>: Feitosa & Krieger 1992; Ulizzi & Zonta 1994:1040; DL Davis et al. 1998; Graffelman & Hoekstra 2000:439; Jongbloet et al. 2001; <i>Multiple Countries</i>: Mackey 1993:192* (in 92/96 countries); DL Davis et al. 1998; Parazzini et al. 1998; Saith & Harriss-White 1999</p>
No signif difference	<p>ASIA <i>Korea</i>: Matsuyama 1944</p> <p>LATIN AMERICA <i>Cuba</i>: Heape 1908a (Blacks)</p> <p>OCEANA <i>Japan</i>: Fukuda et al. 2002* (among smoking parents)</p> <p>INTERNATIONAL <i>Multiple Countries</i>: Mackey 1993:192* (in 4/96 countries)</p>
Females more prevalent	<p>AFRICA <i>South Africa</i>: N Cameron et al. 1998:497 (75% Blacks)</p> <p>ASIA <i>Japan</i>: Sakamoto et al. 2001:94* (in years following widespread methyl mercury pollution); Fukuda et al. 2002 (parents who smoked prior to conception); <i>Taiwan</i>: Yang et al. 2000a (near petroleum refinery)</p> <p>EUROPE <i>Italy</i>: Mocarelli et al. 1996 (in communities near a large dioxin leakage); Mocarelli et al. 2000 (in communities near a large dioxin leakage); Astolfi et al. 2001 (among fathers with the B15 HLA genotype)</p> <p>LATIN AMERICA <i>Columbia</i>: Zaldivar et al. 1991:489 (the Bari)</p> <p>MIDDLE EAST <i>Iran</i>: Saadat et al. 2002* (in high-petroleum air polluted region); <i>Turkey</i>: Jarrell et al. 2002 (mothers exposed to high levels of hexachlorobenzene)</p> <p>INTERNATIONAL <i>Multiple Countries</i>: D Hansen et al. 1999 (severely stressed mothers); WH James 2000:446 (schizophrenic women); <i>Several Industrial Countries</i>: Klasen 1994</p>

By examining the exceptions – i.e., studies in which more females than males were born – one notices that nearly all exceptions involve populations in which one or both parents were exposed to toxic substances or environmental pollutants around the time of conception or during pregnancy. This is consistent with the hypothesis that male fetuses are more vulnerable than their female counterparts to being miscarried if conditions are not close to optimal for maintaining pregnancy (Sakamoto et al. 2001:92). Nevertheless, there may be ethnic-related genetic factors (particularly involving the immune system) that also operate to affect secondary sex ratios (Astolfi et al. 2001).

1.1.1.3c. Sex Ratio at Birth/Hatching (Secondary Sex Ratio) for Non-Humans

Results of the research on the *secondary sex ratio* for nonhuman species are shown in Split-Table 1.1.1.3c. These studies reveal a wide array of conclusions, with about half of the studies finding more males than females being born, while the remaining half have either reported no significant difference or a significantly greater number of females than males born.

Split-Table 1.1.1.3c. Sex ratio at birth/hatching (secondary sex ratio) for non-humans.

Nature of Any Difference	Citations
Males more prevalent	<p>BIRD <i>Bee-eaters</i>: Fry 1972; <i>Grackle</i>: HF Howe 1977; <i>Honeyeater</i>: Dow 1977; <i>Mockingbird</i>: Kinnaird & Grant 1982; <i>Pied Kingfisher</i>: Reyer 1980; <i>Pigeon</i>: Cuenot 1900; LJ Cole & Kirkpatrick 1915:465; <i>Redwing Blackbird</i>: McIlhenny 1940*; JH Myers 1978; <i>Skuas</i>: Kalmbach et al. 2001:2177; <i>Super Blue Wren</i>: Rowley 1965; <i>Tasmanian Hen</i>: Ridpath 1972; <i>Woodpecker</i>: Gowaty & Lennartz 1985; <i>Zebra Finch</i>: von Engelhardt et al. 2004* (under natural conditions)</p> <p>CANINE <i>Fox</i>: Maciejowski 1972; <i>German Shepherd</i>: Whitney 1939; <i>Greyhound</i>: Darwin 1874*; <i>Wolf</i>: Mech 1975; <i>Multiple Species</i>: Ludwig & Boost 1951</p> <p>FELINE <i>Lion</i>: C Packer & Pussey 1987</p> <p>FISH <i>Eelpout Fish</i>: Larsson & Forlin 2002 (eggs that hatched near an industrial pulp mill)</p> <p>INVERTEBRATE <i>Butterfly</i>: Darwin 1874*; <i>Fly</i>: Mohr & Sturtevant 1919; Mohr 1923; TH Morgan et al. 1925; H Redfield 1926; Gershenson 1928; <i>Moth</i>: Rau & Rau 1914:42; <i>Potato Moth</i>: IO Howard 1917:24</p> <p>LAGOMORPH <i>Rabbit</i>: Shaver & Carr 1969 (105/100)</p> <p>MARSUPIAL <i>Opossum</i>: Austad & Sunquist 1986* (under well fed conditions); CN Johnson et al. 2001</p> <p>MUSTELID <i>Mink</i>: Enders 1952</p> <p>PINNIPED <i>Gray Seal</i>: Coulson & Hickling 1961</p> <p>PRIMATE (EXCEPT APE) <i>Macaque</i>: Broadhurst & Jinks 1965; Roonwal & Mohnot 1977; DP Martin 1984; Rawlins & Kessler 1986; Small & Smith 1986; CM Berman 1988; Cheney et al. 1988; Silk 1988; Aureli et al. 1990; Paul & Kuester 1990; Silk et al. 1993; Rhine 1994; Dittus 1998; Bercovitch et al. 2000:3; <i>Prosimian</i>: AB Clark 1978</p> <p>REPTILE: <i>Lizard</i>: A Cree et al. 1995 (when <i>Sphenodon punctatus</i> & <i>Sphenodon gunteri</i> eggs incubated at 22 degrees C); <i>Turtle</i>: D Crews et al. 1994* (when eggs incubated at 26 degrees C)</p> <p>RODENT <i>Mouse</i>: Weldon 1906; Ibsen 1922; MacDowell & Lord 1925; Parkes 1926; Howard et al. 1955; Burley 1982; Machado et al. 2001:1196; <i>Golden Hamster</i>: Sundell 1962 (106/100); <i>Rat</i>: HD King 1918; HD King 1921; Slonaker & Card 1923 (albino rat); HD King 1924; Moriya & Hiroshage 1978* (normal temperature)</p> <p>UNGULATE <i>Cattle</i>: Wilckene 1886*; Johansson 1932; Foote 1973; Maramatsu & Kawanishi 1975* (black angus); Skjervold & James 1979; Behboodi et al. 2001:32; <i>Deer</i>: WC Miller 1932; Robinette et al. 1957; Borg 1971; Dapson et al. 1979; Clutton-Brock et al. 1982; Hewison & Gaillard 1996:462; <i>Horse</i>: Gochlert 1882; <i>Pig</i>: Wilckene 1886*; Parker 1914; McPhee et al. 1931; Nishida et al. 1977; <i>Red Deer</i>: Clutton-Brock et al. 1981; <i>Sheep</i>: Napier & Mullaney 1974</p>
No signif difference	<p>AMPHIBIAN <i>Dart Poison Frog</i>: Bunnell 1973</p> <p>BIRD <i>Great Tit</i>: Oddie & Reim 2002:506; <i>Woodhoopoe</i>: Ligon & Ligon 1990; <i>Woodpeckers</i>: Walters 1990; Koenig & Walters 1999:127</p> <p>CANINE <i>Wild dogs</i>: JR Maloom & Marten 1982</p> <p>FISH <i>Gambusia</i>: Hildebrand 1927</p> <p>INVERTEBRATE <i>Ladybird Beetle</i>: GDD Hurst et al. 1993; Zakharov & Goryacheva 1998</p> <p>MARSUPIAL <i>Opossum</i>: Austad & Sunquist 1986 (under normal feeding)*; <i>Seal</i>: Stirling 1971</p> <p>PRIMATE (EXCEPT APE) <i>Baboon</i>: Rhine et al. 1992; <i>Japanese Macaque</i>: Koyama et al. 1992; Nevison et al. 1996; <i>Redfronted Lemur</i>: Ostner & Kappeler 2004; <i>Rhesus Macaques</i>: MF Small & Smith 1985</p> <p>RODENT <i>Mouse</i>: Weldon 1906</p> <p>UNGULATE <i>Cattle</i>: Pearl 1917a*; Jewell 1921; <i>Deer</i>: Brohn & Robb 1955; Verme & Ozoga 1981:711; <i>Horse</i>: Darwin 1874*; Rasmussen 1940</p>
Females more prevalent	<p>AMPHIBIAN <i>Crocodile</i>: JW Lang 1989; <i>Frog</i>: McVey et al. 1981 (dart-poison frog); Donnelly 1989 (dart-poison frog); Prohl & Berke 2001 (dart-poison frog); Prohl 2002 (dart-poison frog); <i>Green Sea Turtle</i>: Meylan et al. 1990; Allard et al. 1994; <i>Hawksbill Sea Turtle</i>: Broderick et al. 1994; <i>Leatherback Sea Turtle</i>: Dutton et al. 1999; <i>Loggerhead Sea Turtle</i>: Bowen et al. 1993; <i>Mississippi Alligator</i>: JW Lang 1989; <i>Snapping Turtle</i>: Berry & Shine 1980; Kiviat 1980</p> <p>BIRD <i>Blue Tit</i>: Kempnaers 1994; <i>Chicken</i>: Darwin 1874*; Heape 1907*; Pearl 1917b*; Jull 1924; Lambert & Curtis 1929; <i>Grackle</i>: McIlhenny 1940*; <i>Gulls</i>: RG Nager et al. 1999; <i>Zebra Finch</i>: von Engelhardt et al. 2004* (when mothers were treated with estradiol)</p> <p>INVERTEBRATE <i>Ladybird Beetle</i>: Zakharov & Shaikevick 2001; <i>Diptera insect</i>: Hyde 1914; Warren 1918; Lawrence 1940; <i>Dog Tic</i>: E Rawls 1913; TH Morgan et al. 1925; Gershenson 1928; FC Bishopp & Smith 1938:21; <i>Several Parasitic Wasp Species</i>: WD Hamilton 1967</p> <p>PRIMATE (EXCEPT APE) <i>Macaques</i>: JE Bowman & Lee 1995; <i>Spider Monkey</i>: CR Carpenter 1935; LL Klein & Klein 1977; Cant 1978; Symington 1987; CA Chapman & Chapman 1989</p> <p>REPTILE <i>Lizard</i>: Cree et al. 1995* (when <i>Sphenodon gunteri</i> & <i>Sphenodon punctatus</i> eggs incubated at 18 degrees C); <i>Turtle</i>: D Crews et al. 1994* (when eggs incubated at 31 degrees C)</p> <p>RODENT <i>Guinea Pig</i>: Schott & Lambert 1930; <i>Hamster</i>: Labov et al. 1986; <i>Mouse</i>: Sumner et al. 1922; Bluhm 1924; Crew 1925; <i>Rabbit</i>: J Hammond 1934; <i>Rat</i>: King 1924* (wild rat); Rivers & Crawford 1974; Moriya & Hiiroshage 1978* (below normal temperature); Zamiri 1978; <i>Wood Lemming</i>: Maynard Smith & Stenseth 1978; Stenseth 1978</p> <p>UNGULATE <i>Cattle</i>: Darwin 1874*; Maramatsu & Kawanishi 1975* (brown cattle); <i>Deer</i>: Wilckene 1886*; Lowe 1969; Verme 1969; <i>Pig</i>: Parkes 1923; <i>Saharan Arrui</i>: Cassinello & Gomendio 1996:1465; <i>Sheep</i>: Darwin 1874*; Wilckene 1886*; Johansson & Hansson 1943; Skjervold 1979</p>

In most mammalian species, sex is basically determined genetically, but in some types of animals, environmental factors are largely responsible for whether an individual becomes a male or a female. Among amphibians, for example, males are hatched in greatest numbers when the temperature during incubation is “optimal”, but when it becomes “too cold” or “too hot” (but still tolerable), increasingly higher proportions of the hatchlings are females (Freedberg & Wade 2003:178).

A series of studies are worth mentioning to further illustrate factors that influence secondary sex ratios. These studies involved a variety of ladybird beetle (ladybug) that inhabits much of Europe. In one study, nearly four-times as many females were being hatched as males even though earlier studies had found no significant differences in this species’ secondary sex ratio. Investigations revealed that the adult females of this particular subpopulation of beetles (living near Stockholm, Sweden) had been infected by a “male-killing bacterium” which destroyed the male larva (Zakharov & Shaikevich 2001). Overall, many factors can have both short-term and long-term effects on secondary sex ratios.

1.1.1.4. Trends in the Sex Ratio at Birth

A few studies were located which reported on the proportion of males born over time. While all found that more males than females are still being born, some research has documented trends toward decreases in the proportion of males, while others have found increases (Table 1.1.1.4). Racial/ethnic factors may be linked to some of the seeming inconsistencies.

Table 1.1.1.4. Trends in the sex ratio at birth.

Nature of Any Difference	Citations
Increase in the proportion of males	EUROPE <i>Several European Countries</i> : Martuzzi et al. 2001 (1960-1995) NORTH AMERICA <i>United States</i> : Marcus et al. 1998* (1969-1995, Blacks); Nicolich et al. 2000 (1964-1988, non-Whites); D Smith & Von Behren 2005 (during 1980s & 1990s)
No signif difference	NORTH AMERICA <i>United States</i> : D Smith & Von Behren 2005 (during 1970s)
Decrease in the proportion of males	EUROPE <i>Denmark</i> : H Moller 1996 (1970 through 1980s) NORTH AMERICA <i>United States</i> : Marcus et al. 1998* (1969-1995, Whites); Nicolich et al. 2000 (1964-1988, Whites); D Smith & Von Behren 2005 (during 1960s) INTERNATIONAL <i>Several Industrialized Countries</i> : DL Davis et al. 1998 (1960 through early 1990s)

1.1.1.5. Sex Ratio Later in Life

The sex ratio later in life (or the tertiary sex ratio) refers to the proportion of males and females in a population beyond infancy. Split-Table 1.1.1.5 suggests considerable variations in the tertiary sex ratio for various species, including humans. However, as a general rule, among most populations of humans, the sex ratio reaches virtual equality in early adulthood. From then on, it begins to increasingly favor females, so that in elderly populations, there are nearly always more females than males (Jongbloet 2004:769). A major reason for the evening of the sex ratio despite more males than females being born is that males experience higher rates of death throughout childhood, adolescence, and much of adulthood. Evidence pertaining to the higher death rates of males will be presented in Chapter 3.

Split-Table 1.1.1.5. Sex ratio later in life.

Nature of Any Difference	Throughout Childhood	Young & Full Adults	Multiple Age Categories
More males	AFRICA <i>Kenya</i> : Ember 1973:426 (rural) RODENT <i>Marmot</i> : Allaine et al. 2000	CANINE <i>Wolf</i> : Sillero-Zubiri et al. 1996 FISH <i>Barbel</i> : Chenuil et al. 2004:129 RODENT <i>Gerbil</i> : Agren et al. 1989b; <i>Mole Rat</i> : Solomon & Getz 1997	
No signif difference			EUROPE <i>Hungary</i> : Kosa et al. 2002 (Roma Gypsy)
More females		PRIMATE (EXCEPT APE) <i>Baboons</i> : Seyfarth 1976; Bulger & Hamilton 1987; Henzi et al. 1999:241; <i>Redfronted Lemur</i> : Ostner & Kappeler 2004	INTERNATIONAL <i>Multiple Countries</i> : Metropolitan Life Insurance Co. 1949

1.1.1.6. Sex Ratio According to Uterine Location

According to one study, a greater proportion of male fetuses were carried in the right uterine horn and female fetuses in the left uterine horn among gerbils (Table 1.1.1.6).

Split-Table 1.1.1.6. Sex ratio according to uterine location.

Nature of Any Difference	Citation
More males	RODENTS <i>Gerbils</i> : MM Clark et al. 1990* (fetus in right uterine horn)
No signif difference	
More females	RODENTS <i>Gerbils</i> : MM Clark et al. 1990* (fetus in left uterine horn)

1.1.2. Natality Factors

Natality factors are those surrounding the process of birth. Variables to be considered will include such aspects as the length of gestation, miscarriage rates, and prenatal death.

1.1.2.1. Length of Gestation

The time between conception and birth is known as gestation length. Studies have reached inconsistent conclusions regarding any gender differences in gestation length (Table 1.1.2.1).

Table 1.1.2.1. Length of gestation.

Nature of Any Difference	Citations
Males longer	EUROPE <i>Britain</i> : Scheinfeld 1944:28*; <i>Germany</i> : A Scheinfeld 1944:28* NORTH AMERICA <i>United States</i> : Divon et al. 2002 (prolonged pregnancy) BIRD <i>Kestrel</i> : Blanco et al. 2003 (hatch later)
No signif. difference	PRIMATE (EXCEPT APE) <i>Rhesus Macaques</i> : DiGiacomo & Shaughnessey 1972; Bowman & Lee 1995; Bercovitch et al. 2000
Females longer	EUROPE <i>Britain</i> : Robertson 1923:47 NORTH AMERICA <i>United States</i> : NA Anderson & Brown 1943; de Zegher et al. 1999

1.1.2.2. Gestational Development, Rapidity of

The speed with which blastocysts, embryos, and fetuses add weight is referred to as the rapidity of gestational development. Table 1.1.2.2 shows that in all species yet studied, including humans, males develop more rapidly than do females.

Table 1.1.2.2. Gestational development, rapidity of.

Nature of Any Difference	Blastocyst Stage	Embryologic & Fetal Stages
Males more rapid	RODENT <i>Mouse</i> : Tsunoda et al. 1985 UNGULATE <i>Cattle</i> : B Avery et al. 1991*; KP Xu et al. 1992*	EUROPE <i>Britain</i> : FJ Pedersen 1980 NORTH AMERICA <i>United States</i> : PF Ray et al. 1995 RODENT <i>Mouse</i> : Burgoyne et al. 1995; <i>Rat</i> : WJ Scott & Holson 1977 UNGULATE <i>Cattle</i> : B Avery et al. 1991*; B Avery et al. 1992; Xu et al. 1992*; Yadav et al. 1993; Bredbacka & Bredbacka 1996
No signif. difference		
Females more rapid		

1.1.2.3. Pre-Term (Premature) Birthing and Other Birth Complications

Most studies of preterm birthing and birth complications indicate that these events are somewhat more common among males than females (Table 1.1.2.3).

Table 1.1.2.3. Pre-term (premature) birthing and other birth complications.

Nature of Any Difference	Premature Birthing
Higher for males	EUROPE <i>Britain</i> : DM Campbell & MacGillivray 1983; <i>Norway</i> : Vatten & Skjaerven 2004 NORTH AMERICA <i>United States</i> : Karn & Penrose 1951; Cooperstock & Campbell 1996 (Whites); BL Harlow et al. 1996; Cooperstock et al. 1997; Cooperstock et al. 1998* (White twins)
No signif. diff.	NORTH AMERICA <i>United States</i> : Cooperstock et al. 1998* (Black twins)
Higher for females	

1.1.2.4. Prenatal Death (Miscarriages)

According to Table 1.1.2.4, most research with humans as well as with other species indicates that male fetuses are considerably more likely than female fetuses to miscarry.

Table 1.1.2.4. Prenatal death (miscarriages).

Nature of Any Difference	Trimester		Anytime During Pregnancy
	During 1 st Trimester		
Rates higher among males	EUROPE <i>Britain</i> : Hytten 1982; <i>Hungary</i> : Holmes & Goff 1923:247; <i>Vienna</i> : Holmes & Goff 1923:248* NORTH AMERICA <i>United States</i> : MM McMillen 1979*		ASIA <i>Japan</i> : Kajii et al. 1980 EUROPE <i>Belgium</i> : Bertillon 1875; <i>Britain</i> : FA Woods 1939 (Royal families); Dhadijal et al. 1970; Hytten 1982; <i>Germany</i> : Auerbach 1912; Degenhardt & Michaelis 1977*; <i>Netherlands</i> : Wolda 1927 LATIN AMERICA <i>Cuba</i> : Heape 1908a MIDDLE EAST <i>India</i> : Premi 1991 NORTH AMERICA <i>Canada</i> : Wylie 1933; <i>United States</i> : Ciocco 1938; Ciocco 1940; Potter 1940; Scheinfeld 1944:35; Stevenson 1966; Mikamo 1969; Cavalli-Sforza & Bodmer 1971; Naeye et al. 1971; Machin & Crolla 1974; Creasy et al. 1976; G Sutherland et al. 1978; McMillen 1979*; Hassold et al. 1983; T Andrews et al. 1984; Gualtieri & Hicks 1985; Preti et al. 2000; L Ellis & Blanchard 2001:549 BIRD <i>Chicken</i> : Jull 1924; <i>Pheasant</i> : RH Thomas & Huxley 1927:238 CANINE <i>Dog</i> : Whitney 1939 MAMMAL <i>Multiple Species</i> : Crew 1927 RODENT <i>Hamster</i> : Sundell 1962; NC Pratt & Lisk 1989; <i>Rabbit</i> : Maurer & Foote 1971; <i>Rat</i> : HD King 1921 UNGULATE <i>Cattle</i> : JL Edwards et al. 2001:217 (due to heat stress); <i>Deer</i> : Robinette et al. 1957
No signif differ			ASIA <i>Japan</i> : Takahara et al. 1977 EUROPE <i>Sweden</i> : Lauritsen 1976
Rates higher among females	EUROPE <i>Germany</i> : Degenhardt & Michaelis 1977*; <i>Sweden</i> : Lauritsen 1976 NORTH AMERICA <i>United States</i> : Tietze 1948		EUROPE <i>France</i> : Boue 1967; Boue & Boue 1973; Boue et al. 1976; Hassold et al. 1980; Warburton et al. 1980; <i>Sweden</i> : Lauritsen 1976 MIDDLE EAST <i>India</i> : Sudha & Rajan 1999 NORTH AMERICA <i>United States</i> : Warburton et al. 1980 OCEANIA <i>Hawaii</i> : Hassold et al. 1983:42 BIRD <i>Chicken</i> : Jull 1924

1.1.2.5. Perinatal Death (Stillbirth and Death of Infant)

Related to the concept of *miscarriage* is that of *stillbirths*. In fact, some studies of late-stage miscarriages might better be termed as stillbirths. Table 1.1.2.5 indicates that males exhibit higher rates of stillbirths and neonatal deaths than do females. The study conducted specifically on stillbirths found male stillbirths exceeding those for females at a rate of 135 to 100 (Herdan 1952:371).

Table 1.1.2.5. Perinatal death (stillbirth and death of infant).

Nature of Any Difference	Still Born	Death of Infant
More males	EUROPE <i>Sweden</i> : Herdan 1952:371	NORTH AMERICA <i>United States</i> : Ciocco 1940; Scheinfeld 1944:35; Scheinfeld 1944:32; Naeye et al. 1971 MIDDLE EAST <i>Pakistan</i> : Sathar 1987 INTERNATIONAL <i>Several Industrial Countries</i> : Mage & Donner 2004 CANINE <i>Dog</i> : Whitney 1939 MAMMAL <i>Multiple Species</i> : Crew 1927
No signif. difference		
More females		ASIA <i>Bangladesh</i> : Fauveau et al. 1991

1.1.3. Neonatal Physiological Features

Neonatal physiological features primarily have to do with the birth weights and lengths of newborns.

1.1.3.1. Fetal Weight

The limited research on fetal weight suggests that there are few if any sex differences for fetuses and comparable stages in gestation. One study shown in Table 1.1.3.1 indicated that male fetuses weighed more, while the remaining two studies found no significant differences.

Table 1.1.3.1. Fetal weight.

Nature of Any Difference	Citations
Higher in males	EUROPE <i>Britain</i> : Pedersen 1980
No significant difference	ASIA <i>Japan</i> : Tezuka et al. 1998 EUROPE <i>Britain</i> : Selbing & McKay 1985
Higher in females	

1.1.3.2. Birth Weight

Many studies have investigated gender differences in birth weight. Across all species yet studied, including humans, studies have found males averaging greater weight at delivery than females (Table 1.1.3.2).

Table 1.1.3.2. Birth weight.

Nature of Any Difference	Citations
Higher in males	AFRICA <i>South Africa</i> : N Cameron et al. 1998:499 ASIA <i>Japan</i> : Miwa in TB Robertson 1923:474; <i>Russia</i> : Tschepourkovsky in TB Robertson 1923:474; V Vickers & H Stuart 1943:155 EUROPE : <i>Britain</i> : K Pearson 1900; Pearson in TB Robertson 1923:474; Tully et al. 2004:220 (twins); <i>Denmark</i> : Heiberg in TB Robertson 1923:474; <i>Finland</i> : Taittonen et al. 1996:628; <i>France</i> : Guihard-Costa et al. 2002:30 MIDDLE EAST <i>Lebanon</i> : Usta & Nassar 2004:196 NORTH AMERICA <i>United States</i> : Evezky 1881; Stockton-Hough 1885; WH Morse 1886:393; CW Townsend 1887; LE Holt 1897; Hrdlicka 1898; Hollingsworth & Montague 1914; Bowditch in TB Robertson 1923:474; NA Anderson & Brown 1943; LM Terman & Tyler 1954; HJ Hoffman et al. 1974; AJ Parker et al. 1984 (intrauterine growth rate); Marsal et al. 1996 (intrauterine growth rate); TB Gage & Therriault 1998:518; de Zegher et al. 1999 OCEANIA <i>Australia</i> : TB Robertson 1923:474 BIRD <i>Great Reed Warbler</i> : Nishiumi et al. 1996; Westerdahl et al. 1997; <i>Yellow-Headed Blackbird</i> : CB Patterson et al. 1980 PRIMATE (EXCEPT APE) <i>Baboon</i> : McMahon et al. 1976; <i>De Brazza's Monkey</i> : Valerio & Dalgard 1975; <i>Long-Tail Macaque</i> : Dang et al. 1992; <i>Orangutans</i> : A Seitz 1969; <i>Rhesus Macaque</i> : DiGiacomo & Shaugnessy 1972; Riopelle & Hale 1975; ES Watts 1977; Bercovitch et al. 2000 UNGULATE <i>Cattle</i> : Behboodi et al. 2001:33; <i>Deer</i> : Espmark 1971; Robinette et al. 1973; Nowosad 1975; McCullough 1979
No signif. difference	PRIMATE (EXCEPT APE) <i>Long-tailed Macaque</i> : Willes et al. 1977; <i>Pig-tailed Macaque</i> : Willes et al. 1977
Higher in females	

1.1.3.3. Birth Weight Depression

According to two studies, male birth weight is depressed more than female birth weight among babies whose mothers experience persistent oxygen deprivation in the Andes of Bolivia (Table 1.1.3.3).

Table 1.1.3.3. Birth weight depression.

Nature of Any Difference	Citations
Male weight depressed more	LATIN AMERICA <i>Bolivia</i> : Haas 1976 (due to high altitude); Hass et al. 1980 (due to high altitude)
No significant difference	
Female weight depressed more	

1.1.3.4. Birth Weight, Individual Variability in

One study that investigated variability in birth weight concluded that males exhibited greater variability than did females, while the other study concluded that there were no significant sex differences (Table 1.1.3.4).

Table 1.1.3.4. Birth weight, individual variability in.

Nature of Any Difference	Citations
Males exhibit more	EUROPE <i>Britain</i> : BT Baldwin 1923:27
No significant difference	NORTH AMERICA <i>United States</i> : Hollingsworth & Montague 1914
Females exhibit more	

1.1.3.5. Birth Length

Most research concerning gender differences in the length of babies at birth have concluded that baby boys are longer than baby girls. The earliest study to be conducted (in the late 1800s) failed to find a statistically significant difference (Table 1.1.3.5).

Table 1.1.3.5. Birth length.

Nature of Any Difference	Citations
Males longer	EUROPE <i>Britain</i> : K Pearson 1900; <i>Several European Countries</i> : TB Robertson 1923:476 NORTH AMERICA <i>United States</i> : Hollingsworth & Montague 1914
No significant difference	NORTH AMERICA <i>United States</i> : LE Holt 1897
Females longer	

1.1.3.6. Birth Length, Individual Variability in

One study of variability in birth length found greater variability among the males than was true for the females (Table 1.1.3.6).

Table 1.1.3.6. Birth length, individual variability in.

Nature of Any Difference	Citations
Males more variable	EUROPE <i>Britain</i> : BT Baldwin 1923:27
No significant difference	
Females more variable	

1.1.4. Reproductive and Genetic Factors

As the concept is being used here, reproductive factor are those having to do with fertility, which is usually measured in terms of the number of offspring individuals or couples have. Also considered in this section will be studies pertaining to genetic differences between the sexes.

1.1.4.1. Spacing Between Offspring (Birth Spacing)

Some studies have investigated the possibility that the spacing between births might vary depending upon the sex of the preceding child. The rationale behind these studies surrounds the observation that in most countries couples prefer having boys over girls (see Chapter 12). Therefore, couples would be expected to delay having additional children more once they had given birth to a boy. As shown in Table 1.1.4.1, the evidence at this point is mixed with regard to this line of reasoning.

Table 1.1.4.1. Spacing between offspring (birth spacing).

Nature of Any Difference	Citation
Longer after males	AFRICA <i>Kenya</i> : Mace & Sear 1997 (pastoralist tribe) ASIA <i>Vietnam</i> : Swenson & Thang 1993
No signif difference	
Longer after females	NORTH AMERICA <i>United States</i> : Margulis et al. 1993 (Hutterites)

1.1.4.2. Reproductive Success/Fertility, Individual Variability in

In terms of the total number of offspring had, the sexes must be exactly equal, since every offspring in a sexually reproducing species must have a mother and a father. However, there remains the possibility that one sex can exhibit greater variability in producing offspring than the other sex.

The concept of *reproductive success* (RS) is central to the Darwinian evolutionary theory. While the term is conceptually simple – i.e., the number of copies of an individual's genes found in subsequent generations – precisely measuring it can be difficult (Ellis 1995:261). Obstacles to precise measurement of RS include the fact that that the concept does not simply mean the number of offspring an individual produces but the number of offspring those offspring produce as well, etc. This indicates that the most exact measure of RS would require researchers to follow an individual's progeny over a multitude of generations. Another aspect of RS that makes it difficult to measure comes from noting that an individual's genes can be passed on to future generations not only by having offspring oneself, but also by helping close relatives bear and rear offspring. This is because close relatives also carry many of the same genes as do a given individual.

Added to the above nuances in the concept of RS difficulties is the fact that in most species, RS is easier to measure in females than in males. This is especially true because females are better equipped than males to identify and to bond with their offspring immediately after giving birth. With these stipulations in mind, one can see from Table 1.1.4.2 that the evidence largely suggests that males exhibit greater variability in RS than is true for females.

Table 1.1.4.2. Reproductive success/fertility, individual variability in.

Nature of Any Difference	Citations
Males more varied	AFRICA <i>South Africa</i> : Howell 1979 (!Kung tribe) LATIN AMERICA <i>Columbia</i> : Zaldivar et al. 1991:485 (Bari, due to polygamy); <i>Paraguay</i> : K Hill & Hurtado 1996 (Ache) NORTH AMERICA <i>Canada</i> : Greenglass 1993:981 (managers); <i>United States</i> : Laumann 1994:444; TJ Hoff 2004:306 (doctors) AMPHIBIAN <i>Frog</i> : Prohl & Hodl 1999 MAMMAL <i>Gray Seal</i> : SS Anderson & Fedak 1987; Godsell 1991; Lidgard et al. 2001 REPTILE <i>Lizard</i> : Trivers 1972
No signif. difference	AFRICA <i>South Africa</i> : Draper & Hames 2000:144
Females more varied	BIRD <i>Spotted Sand Piper</i> : Oring et al. 1991 (upper range variability)

1.1.4.3. Relationship Between Age and Reproductive Success

One study among birds concluded that there was a stronger positive relationship between age and annual reproductive success in males than in the case of females (Table 1.1.4.3).

Table 1.1.4.3. Relationship between age and reproductive success.

Nature of Any Difference	Citations
Stronger for males	BIRD <i>Cassin's Auklets</i> : Pyle et al. 2001 (annual RS)
No signif difference	
Stronger for females	BIRD <i>Bowerbirds</i> : Vellenga 1980 (reproducing at younger age); <i>Peacocks</i> : JT Manning 1989 (reproducing at younger age)

1.1.4.4. Relationship Between Aggression and Reproductive Success

According to one study, aggressive tendencies were more strongly related to the reproductive success of males than to that of females (Table 1.1.4.4). In other words, the most aggressive males sired the most offspring, whereas for females, aggression had less to do with offspring produced.

Table 1.1.4.4. Relationship between aggression and reproductive success.

Nature of Any Difference	Citation
Stronger for males	AMPHIBIAN <i>Anolis Carolinensis</i> : TA Jenssen & Nunez 1998
No signif difference	
Stronger for females	

1.1.4.5. Genetic Contributions to the Body Mass Index

The body mass index (BMI) has been shown to be heritable, meaning that genes play a sizable role in determining how heavy one will be after controlling for height (Pietilainen et al. 1999). These studies were designed to assess the extent to which genetics contributes to one's BMI. As shown in Table 1.1.4.5, the findings have been inconsistent regarding an sex difference in this regard.

Table 1.1.4.5. Genetic contributions to the body mass index.

Nature of Any Difference	Prepubertal		Postpubertal	
	Childhood	Adolescent	Adult	
More in males		EUROPE <i>Finland</i> : Korkeila et al. 1991 (twins)	NORTH AMERICA <i>United States</i> : Stunkard et al. 1990 (twins reared apart)	
No signif. difference		EUROPE <i>Finland</i> : Pietilainen et al. 1999* (17 year olds)		
More in females	EUROPE <i>England</i> : Brook et al. 1975	EUROPE <i>Finland</i> : Pietilainen et al. 1999* (16 year olds)	EUROPE <i>Germany</i> : Neals & Cardon 1992 (twins); <i>Norway</i> : Harris et al. 1995 (twins)	NORTH AMERICA <i>United States</i> : DB Allison et al. 1994 (twins)

1.1.4.6. Genetic Contributions to Development

One study indicated that the IGF-1 gene promoted the growth of males more than the growth of females (Table 1.1.4.6).

Table 1.1.4.6. Genetic contributions to development.

Nature of Any Difference	Citation
Males more	EUROPE <i>Netherlands</i> : Rietveld et al. 2004 (height promoted by the IGF-1 gene)
No signif difference	
Females more	

1.1.4.7. Genetic Mutations

Two studies have indicated that males exhibit greater DNA damage in their rectal cells than do females (Table 1.1.4.7).

Table 1.1.4.7. Genetic mutations.

Nature of Any Difference	Citation
More in males	EUROPE <i>Germany</i> : Pool-Zobel et al. 1999 (greater DNA damage in rectal cells); Pool-Zobel et al. 2004 (greater DNA damage in rectal cells)
No signif difference	
More in females	

1.1.4.8. SRY Gene

SRY is a gene located on the Y chromosome. It begins the biochemical cascading process that causes the undifferentiated gonad to develop into a testis. As such, the SRY gene is essentially exclusive to males, a fact documented in one study presented in Table 1.1.4.8.

Table 1.1.4.8. SRY gene.

Nature of Any Difference					Postpubertal
					Adult
More in males					EUROPE <i>Germany</i> : Mayer et al. 1998 (hypothalamus, frontal cortex, temporal cortex)
No signif. difference					
More in females					

1.1.4.9. ZFY Gene

Like the SRY gene (see above), the ZFY gene is located on the Y chromosome and it is found almost exclusively among genetic males (Table 1.1.4.9).

Table 1.1.4.9. ZFY gene.

Nature of Any Difference					Postpubertal
					Adult
More in males					EUROPE <i>Germany</i> : Mayer et al. 1998 (hypothalamus, frontal cortex, temporal cortex)
No signif. difference					
More in females					

1.1.5. Maturation and Development

The sex differences subsumed maturation and development have to do with the rate at which males and females progress through various key physiological stages of life, with the onset of puberty being a particularly significant one.

1.1.5.1. Physical Maturation Rate in Utero

According to one study, fetal physical maturation occurs more rapidly among females than among males (Table 1.1.5.1).

Table 1.1.5.1. Physical maturation rate in utero.

Nature of Any Difference	Citation
More rapid in males	
No signif difference	
More rapid in females	EUROPE <i>Belgium</i> : M Lampl & Jeanty 2003 (opposite-sex twins)

1.1.5.2a. Physical Maturation Rate Following Birth

Physical maturation rates are assessed in various ways depending in part on the age and the species of the subjects. For sub-adolescents, assessment usually involves measures of the rate of skeletal growth. The studies summarized by Table 1.1.5.2 pertaining to humans indicates that females mature more rapidly than do males. This is consistent with a meta-analysis performed on prepubertal humans regarding the rapidity with which both sexes develop through various key behavioral milestones, such as walking and talking (Cohn 1991).

Table 1.1.5.2. Physical maturation rate following birth.

Nature of Any Difference	Prepubertal				Postpubertal	
	Infant	Toddler	Early Child.	Childhood	Adolescent	Adult
More rapid in males						
No signif. difference				EUROPE Croatia: M Zivicnjak et al. 2003 (until 9 years old)		
More rapid in females	NORTH AMERICA <i>United States:</i> A Scheinfeld 1944:27 (skeletal development); Darley & Winitz 1961 (speech organs); Eichorn 1968 (skeletal development); Held et al. 1984 (4-9 month olds, vernier acuity); Bauer et al. 1986 (4-9 moth olds, binocularity)	NORTH AMERICA <i>United States:</i> Mead 1913; Flory 1935*; Bayley 1940 (bone development); Bayley 1943 (skeletal development); Kagan & Lewis 1965	NORTH AMERICA <i>United States:</i> Flory 1935* (skeletal development)	NORTH AMERICA <i>United States:</i> Beik 1913; Baldwin 1922; Flory 1935* (skeletal development); A Scheinfeld 1944:46 (skeletal development)	EUROPE Britain: Tanner 1966 (height velocity) NORTH AMERICA <i>Canada:</i> AM Thompson et al. 2003:1688 (height velocity); <i>United States:</i> Baldwin 1922; Flory 1935* (skeletal development); Tanner et al. 1966*; Tanner et al. 1976	EUROPE Britain: LT Higgins et al. 2002:87 (sexual maturity, college) NORTH AMERICA <i>United States:</i> Hutt 1972 (young)

1.1.5.2b. Physical Maturation Rate Following Birth Among Nonhumans

Unlike the research with humans, the limited findings from nonhumans indicate that males mature more rapidly than do females (Table 1.1.5.2b).

Table 1.1.5.2b. Physical maturation rate following birth among nonhumans.

Nature of Any Difference	Postpubertal			Multiple Age Categories
			Adult	
More rapid in males			RODENT Rat: Varma & Meguid 2001:399 (growth in weight)	INVERTEBRATES Mealworm: Hein 1920:240 (growth in length)
No signif. difference				
More rapid in females				

1.1.5.3. Onset of Puberty, Age at

The *onset of puberty* is usually marked by various physical changes. In females, it begins with the first menstruation (known as *menarche*). In males, the voice begins to lower, and in both sexes the growth of pubic hair begins. Even though different types of measures for the onset of puberty are used for males and females, one can see from Table 1.1.5.3 that all studies agree that females begin exhibiting signs of puberty earlier than is the case for males. Most studies have found the difference to be about 1.5 years (Sheehy et al. 1999).

Table 1.1.5.3. Onset of puberty, age at.

Nature of Any Difference	Citation
Earlier in males	
No signif. difference	
Earlier in females	EUROPE Britain: Tanner et al. 1976; <i>Finland:</i> Kaltiala-Heino et al. 2003:537; <i>Germany:</i> Largo et al. 1978; Sheehy et al. 1999; <i>Norway:</i> Storvoll & Wichstrom 2002:190 (self-reports); <i>Sweden:</i> Lindgren 1978 NORTH AMERICA Canada: Marcotte 2002; <i>United States:</i> Flory 1935; Willoughby 1935; AC Petersen & Crockett 1985; Sagrenstano et al. 1999:100 (Blacks); Offer et al. 1996

1.1.5.4. Timing of Pubertal Growth Spurt

Studies have consistently found that the timing of the pubertal growth spurt is earlier in females than it is in males (Table 1.1.5.4).

Table 1.1.5.4. Timing of pubertal growth spurt.

Nature of Any Difference	Citation
Earlier in males	
No signif difference	
Earlier in females	ASIA Japan: Ashizawa 1970; JM Tanner et al. 1982; Ali & Ohtsuki 2000; Ali et al. 2000 EUROPE Britain: JM Tanner et al. 1976; Dangour et al. 2002:294 (adolescent growth spurt onset); Poland: Bielicki 1975; Bielicki et al. 1984; Sweden: Karlberg 1989 NORTH AMERICA United States: Ledford & Cole 1998 OCEANIA Australia: T Brown & Townsend 1982 (aborigines)

1.2

MORPHOLOGY AND PHYSIOLOGY

Morphology refers to all aspects of an animal's physical appearance or external anatomy. Some of the most widely investigated morphological traits regarding possible sex differences have to do with body size, height, and weight. Others involve body proportion. Results of these investigations are summarized below.

1.2.1. Body Size, Height, and Weight

Many studies have sought to assess the extent to which males and females differ in body size. The findings are summarized below.

1.2.1.1a. Height Among Prepubertal Humans

Because a tremendous amount of research is available on gender differences in height, the findings are presented in four tables: one each for prepubertals, young adolescents, and older adolescents and adults. Regarding prepubertal humans, the evidence fails to be consistent in indicating which gender is taller although for infants, all except one study suggest that, on average, males surpass females in height. For toddlers and preschool children, most studies have concluded that males are taller or that there are no significant differences. Among school age children (roughly ages 6-11), the results become even more mixed (Split-Table 1.2.1.1a).

Split-Table 1.2.1.1a. Height among prepubertal humans.

Nature of Any Difference				
	Infant	Toddler	Early Childhood	Childhood
Males taller	AFRICA South Africa: N Cameron et al. 1998:499* NORTH AMERICA United States: Stockton-Hough 1885 (19 th Century); GM West 1893; DB Gardner & Swigerm 1958 (adoptees); J Bernard 1964 (adoptees)	AFRICA South Africa: N Cameron et al. 1998:499*	AFRICA South Africa: N Cameron et al. 1998:499* EUROPE Britain: Habbukuk 1926*; Dangour et al. 2002*; Scotland: Elderton 1914* LATIN AMERICA Peru: de Meer et al. 1993:66 NORTH AMERICA Canada: F Boas 1897*; United States: F Boas 1897*	EUROPE Britain: Kuh et al. 1991; Dangour et al. 2002*; Scotland: Elderton 1914* NORTH AMERICA United States: Bowditch 1872 (19 th Century)*; Anonymous 1893:41 (19 th Century); JA Gilbert 1893:91 (19 th Century); WT Porter 1892:180 (19 th Century)*; Roche & Malina 1983:204; Perry et al. 2001:2992*; Bogin et al. 2002 (Hispanic)
No signif. difference		EUROPE France: Variot & Chaumet cited in TB Robertson 1923:503*	ASIA Japan: Hashiga cited in TB Robertson 1923:503* EUROPE France: Variot & Chaumet cited in TB Robertson 1923:503* NORTH AMERICA United States: Perry et al. 2001:2992* OCEANIA Philippines: Bobbit cited in TB Robertson 1923:503*	ASIA Japan: Hashiga cited in TB Robertson 1923:503* EUROPE Austria: Kirchengast & Steiner 2001; Britain: British Board of Health cited in Robertson 1923:502*; France: Variot & Chaumet cited in TB Robertson 1923:503*; Germany: Gasser et al. 2000*; Italy: Pagliani cited in TB Robertson 1923:503* NORTH AMERICA Canada: F Boas 1897*; AM Thompson et al. 2003:1686; United States: GM West 1893:4 (19 th Century); F Boas 1897*; Malina et al. 1973; Perry et al. 2001:2992* OCEANIA New Zealand: EC Rush et al. 2003:4; Philippines: Bobbit cited in TB Robertson 1923:503*
Females taller	NORTH AMERICA United States: LE Holt 1897 (19 th Century)*	NORTH AMERICA United States: LE Holt 1897 (19 th Century)*		ASIA Japan: Satake et al. 1995 EUROPE Sweden: Lindgren 1978* OCEANIA Australia: Magarey et al. 1999:140*; Fiji & Samoa: Satake et al. 2001:276* (late childhood)

1.2.1.1b. Height Among Young Adolescent Humans

Studies for height among young adolescent humans are mixed with nearly equal amounts showing either females to be taller or no significant difference between males and females. Only one study in Split-Table 1.2.1.1b indicates that young male adolescents are taller than the females of the same age.

Split-Table 1.2.1.1b. Height among young adolescent humans.

Nature of Any Difference	Young Adolescent
Males taller	NORTH AMERICA <i>United States</i> : Perry et al. 2001:2992*
No signif. difference	ASIA <i>China</i> : AM McManus et al. 2004:603; <i>Japan</i> : Hashiga cited in TB Robertson 1923:503*; Kouda et al. 2003:1107; Kouda et al. 2004:80 EUROPE <i>Britain</i> : British Board of Health cited in Robertson 1923:502*; <i>France</i> : Variot & Chaumet cited in TB Robertson 1923:503*; <i>Italy</i> : Pagliani cited in TB Robertson 1923:503*; <i>Scotland</i> : Elderton 1914; <i>Sweden</i> : Key cited in TB Robertson 1923:503* NORTH AMERICA <i>Canada</i> : AM Thompson et al. 2003:1686; <i>United States</i> : GF Peckham 1881:61 (19 th Century); Holt cited in Robertson 1923:502*; Roche & Malinal 1983:204 OCEANIA <i>Philippines</i> : Bobbit cited in TB Robertson 1923:503*
Females taller	ASIA <i>Japan</i> : Satake et al. 1995 EUROPE <i>Britain</i> : Dangour et al. 2002; <i>Croatia</i> : M Zivicnjak et al. 2003; <i>Germany</i> : Gasser et al. 2000* <i>Sweden</i> : Lindgren 1978* NORTH AMERICA <i>Canada</i> : F Boas 1897*; <i>United States</i> : Bowditch 1872; JM Greenwood 1891*; WT Porter 1892:180*; Anonymous 1893:41; JA Gilbert 1893:91; JA Gilbert 1894*; F Boas 1897*; JA Gilbert 1897*; WW Hastings 1900; FW Smedley 1902; Holt cited in Robertson 1923:502*; Perry et al. 2001:2992* OCEANIA <i>Fiji & Samoa</i> : Satake et al. 2001:276*

1.2.1.1c. Height Among Older Adolescents

Split-Table 1.2.1.1c continues to present findings for humans concerning gender differences in height. Unlike the research based on sub-adolescents and young adolescents, by late adolescence (i.e., following age 15), male height, on average, consistently surpasses that of females (TB Robertson 1923:503; JP Gray & Wolfe 1980; Guegan et al. 2000:2529).

Split-Table 1.2.1.1c. Height among older adolescent humans.

Nature of Any Difference	Older Adolescent
Males taller	ASIA <i>China</i> : AM McManus et al. 2004:603; <i>Japan</i> : Ali et al. 2001; Kouda et al. 2003:1107 EUROPE <i>Britain</i> : British Board of Health cited in Robertson 1923:502*; Hauspie et al. 1985*; Dangour et al. 2002; <i>Denmark</i> : Roepstorff et al. 2002:E43b (young); <i>Finland</i> : Pietilainen et al. 1999 (16-17 year olds); <i>France</i> : Variot & Chaumet cited in TB Robertson 1923:503*; <i>Germany</i> : Gasser et al. 2000*; <i>Italy</i> : DeVito et al. 1999:651*; <i>Sweden</i> : Lindgren 1978* MIDDLE EAST <i>India</i> : Hauspie et al. 1985*; <i>Turkey</i> : Tan. 2003: 1352 (older adolescents) NORTH AMERICA <i>Canada</i> : F Boas 1897*; AM Thompson et al. 2003:1686*; <i>United States</i> : Bowditch 1872 (19 th Century)*; GF Peckham (19 th Century) 1881:61 (19 th Century); JM Greenwood 1891 (19 th Century)*; JA Gilbert 1893:91 (19 th Century); JA Gilbert 1894 (19 th Century)*; F Boas 1897*; JA Gilbert 1897 (19 th Century)*; Holt cited in Robertson 1923:502*; Krogman 1970; Hamill et al. 1973; Malina et al. 1974; Roche & Malina 1983:204 OCEANIA <i>Australia</i> : Magarey et al. 1999:140* (after age 15); <i>Philippines</i> : Bobbit cited in TB Robertson 1923:503*
No signif. difference	
Females taller	

1.2.1.1d. Height Among All Adult Humans

As shown in Split-Table 1.2.1.1d, all studies of adults have concluded that males are taller on average than females.

Split-Table 1.2.1.1d. Height among all adult humans.

Nature of Any Difference	Adult	Multiple Age Categories
Males taller	<p>AFRICA <i>Egypt</i>: Valsik et al. 1970 (Nubians); <i>Fiji</i>: Clegg 1989; <i>Mongolia</i>: Vlcek 1965; <i>South Africa</i>: Shapira 1930 (Hottentots tribe); Brauer 1982 (IKung tribe); Tobias 1989 (Bantu); <i>Tanzania</i>: Sellen 1995 (Maasai tribe); <i>West Africa</i>: Prazuck et al. 1988 (Fulani & Mossi); <i>Sub-Saharan Africa</i>: Rattray 1923:332 (Ashanti Tribe); Orr & Gilks 1931:77 (various tribes); Hiernaux 1968 (various tribes); Holden & Mace 1999 (various tribes)</p> <p>ASIA <i>Hong Kong</i>: Luo et al. 1999*; Lei et al. 2004:73 (elderly); <i>Russia</i>: Smirnova 1979 (Siberians); W Leonard et al. 1996 (Siberia); <i>Taiwan</i>: Chai 1967; <i>Several Asian Countries</i>: K Kennedy 1984 (Neolithic Asia)</p> <p>EUROPE <i>Britain</i>: Annandale & Hunt 1990:35; AH Baker & Wardle 2003; <i>Denmark</i>: AN Pedersen et al. 2002 (elderly, 80 years old); <i>Finland</i>: Auger et al. 1980; Rosenbaum et al. 1985; Geelen et al. 2002:1403; <i>France</i>: Ochala et al. 2004:442 (elderly); <i>Germany</i>: G Shan & Bohn 2003* (young); <i>Ireland</i>: Hooton et al. 1955; <i>Italy</i>: DeVito et al. 1999:651* (young); Perissinotto et al. 2002 (elderly); <i>Norway</i>: HE Meyer & Selmer 1999:221; <i>Sweden</i>: Luo et al. 1999*; <i>Several European Countries</i>: RB Bean 1923:8 (young); Meiklejohn et al. 1984 (Neolithic Europe); deGroot et al. 1991 (elderly); Dey et al. 1999 (elderly)</p> <p>LATIN AMERICA <i>Brazil</i>: Neves et al. 1985; Stinson 1990; <i>Columbia</i>: Steggerda 1963; <i>Guiana</i>: Gillin 1936; <i>Mexico</i>: McCullough 1982 (Maya); <i>Peru</i>: Benfer 1984 (~5000 yrs ago); <i>Several South American Tribes</i>: Steggerda 1963; <i>Several Latin American Countries</i>: Comas 1971</p> <p>MIDDLE EAST <i>India</i>: H Field 1970; Ganguly 1979; <i>Iran</i>: Ayatollahi & Carpenter 1993; <i>Saudi Arabia</i>: Khalid 1995; <i>Lebanon</i>: P Smith et al. 1984 (Late Paleolithic Levant)</p> <p>NORTH AMERICA <i>Canada</i>: Jenness 1923; Birkbeck & Lee 1973 (Nootka people); Auger et al. 1980; Ledoux et al. 1997; Marliss et al. 2000:458 (young); <i>United States</i>: Hrdlicka 1935 (Pueblos, Navajo); RL Jackson & Kelly 1945; Skeller 1954 (Alaska Inuit); P Miller 1970 (Apache Indians); WM Moore 1972 (Navajo Indians); DC Cook 1984 (pre-Columbian); AH Goodman et al. 1984 (pre-Columbian); CS Larsen 1984 (pre-Columbian, ~3000 yrs ago); Perzigian et al. 1984 (pre-Columbian, ~3000 yrs ago); Comuzzie et al. 1993:730 (Mexican Americans); Kwo et al. 1998:1554 (young); al'Absi et al. 1999:334; Jantz & Jantz 1999; Pritzlaff et al. 1999 (men taller); Nopoulos et al. 2000; AS Jackson et al. 2002:791; Treiber et al. 2002:709; Karasik et al. 2003:311; Shan & Bohn 2003* (young); Nicolay & Walker 2005:607</p> <p>OCEANIA <i>Australia</i>: MJ Barrett & Brown 1971 (aborigines); Pretty et al. 1998; Duan et al. 2001:2271; A Wright et al. 2002:286 (young); <i>New Guinea</i>: Wolstenholme & Walsh 1967; LA Malcolm 1969; BH Heath & Carter 1971; Littlewood 1972; Hyndman et al. 1989; Ulijaszek 1993; <i>Solomon Islands</i>: LB Page et al. 1977; <i>Tokelau Island</i>: Prior et al. 1977</p> <p>INTERNATIONAL <i>Multiple countries</i>: Murdock & White 1969 (73 out of 73 countries); Eveleth & Tanner 1976; Gray & Wolfe 1980; Guegan et al. 2000</p>	<p>ASIA <i>Japan</i>: Satake et al. 1995</p> <p>EUROPE <i>Britain</i>: Bjelke 1971; RR Baker & Bellis 1993:872; Formicola 1993:355 (Neolithic skeletal remains); <i>Sweden</i>: Kuskowska-Wolk et al. 1991</p> <p>LATIN AMERICA <i>Mexico</i>: Steggerda 1941:154 (ancient Mayan skeletal remains); TD Steward 1953:299 (ancient Mayan skeletal remains); WA Haviland 1967 (ancient Mayan skeletal remains)</p> <p>NORTH AMERICA <i>United States</i>: AS Pierson et al. 1974; D Miller 1990</p> <p>OCEANIA <i>Fiji</i>: Satake et al. 2001:276*; <i>Samoa</i>: Satake et al. 2001:276*</p> <p>HOMINID <i>Australopithecus</i>: Wolpoff 1980 (fossils); Aiello 1994 (fossils); MG Leakey et al. 1995 (fossils); Richmond & Jungers 1995 (fossils); MG Leakey et al. 1998 (fossils)</p>
No signif. difference		
Females taller		

1.2.1.2. Height/Length, Individual Variability in

Studies that have sought to determine if males or females exhibit greater variability in height have been confined to adolescents and adults. Table 1.2.1.2 shows that all studies have documented greater variability among males than among females.

Table 1.2.1.2. Height/length, individual variability in.

Nature of Any Difference	Postpubertal				Multiple Age Categories
				Adult	
Males more varied				<p>EUROPE <i>Netherlands</i>: Roede & van Wieringen 1985; Fredriks et al. 2000; Rietveld et al. 2004:196</p>	<p>EUROPE <i>Britain</i>: Acheson & Fowler 1964</p> <p>NORTH AMERICA <i>United States</i>: Froelich 1970 (Hawaii, adult)</p> <p>INTERNATIONAL <i>Multiple countries</i>: Formicola 1993:355 (European Neolithic skeletons)</p> <p>INSECT <i>Mealworms</i>: Hein 1920:240</p>
No signif. difference					
Females more varied					

1.2.1.3. Sitting Height (Length of Trunk)

To measure sitting height, subjects are asked to sit in a chair while the researcher measures the distance from the chair's seat to the top of each subject's head. Studies in Table 1.2.1.3 have come to conflicting conclusions regarding any sex difference in sitting height, with the possible exception of studies in late adolescence and adulthood, where males appear to be taller in sitting height.

Table 1.2.1.3. Sitting height (length of trunk).

Nature of Any Difference	Prepubertal				Postpubertal		
	Infant	Toddler	Early Child.	Childhood	Adolescent		Adult
					Early	Late	
Male trunk length longer		EUROPE Germany: Gasser et al. 2000*				EUROPE Belgium: Koziel et al. 1995; Britain: Hauspie et al. 1985; Dangour et al. 2002* OCEANIA Fiji & Samoa: Satake et al. 2001:276*	EUROPE Germany: G Shan & Bohn 2003* (young) NORTH AMERICA United States: G Shan & Bohn 2003* (young)
No signif. difference	NORTH AMERICA United States: Stockton-Hough 1885; GM West 1893		EUROPE Germany: Gasser et al. 2000*	OCEANIA Fiji & Samoa: Satake et al. 2001:276*	OCEANIA Fiji & Samoa: Satake et al. 2001:276*		
Female trunk length longer					EUROPE Britain: Dangour et al. 2002* NORTH AMERICA United States: FW Smedley 1902:58		

1.2.1.4a. Weight Among Prepubertal Humans

To accommodate the large number of studies, the table on sex differences in weight has been split, with one portion pertaining to prepubertals and the other pertaining to adolescents and adults. Numerous studies have assessed sex differences in weight among prepubertals. As shown in Split-Table 1.2.1.4a, most studies have shown that males weigh more than females throughout childhood.

Split-Table 1.2.1.4a. Weight among prepubertal humans.

Nature of Any Difference	Prepubertal			
	Infant	Toddler	Early Childhood	Childhood
Males weight more	AFRICA South Africa: N Cameron et al. 1998:499* (75% Blacks) NORTH AMERICA United States: Stockton-Hough 1885 (19 th century); GM West 1893; Almli et al. 2001:257 (in utero & neonate)	AFRICA South Africa: N Cameron et al. 1998:499* (75% Blacks) ASIA China: Tam et al. 1999:510 EUROPE France: Variot & Chaumet cited in JA Robertson 1923:501* NORTH AMERICA United States: LE Holt 1897* (19 th Century)	AFRICA South Africa: N Cameron et al. 1998:499* (75% Blacks) ASIA Japan: Miwa in JA Robertson 1923:501*; Miwa in TB Robertson 1923:501 EUROPE Britain: Habbukuk 1926*; Italy: Pagliani in Robertson 1923:501* NORTH AMERICA United States: Holt in TB Robertson 1923:500*; Porter cited in TB Robertson 1923:500*	ASIA Japan: Miwa cited in JA Robertson 1923:501* EUROPE Italy: Pagliani cited in Robertson 1923:501*; Scotland: TJ Cole et al. 2000; Sweden: Key cited in Robertson 1923:501* NORTH AMERICA Canada: F Boas & Wissler 1897*; United States: F Boas & Wissler 1897*; Holt cited in TB Robertson 1923:500*; Porter cited in TB Robertson 1923:500*; McNemar & Terman 1936:24*; Roche & Malina 1983:204*; Perry et al. 2001:2992*
No signif. difference	NORTH AMERICA United States: LE Holt 1897* (19 th Century); DG Gardner & Swiger 1958 (adoptees)		NORTH AMERICA United States: Perry et al. 2001:2992*	EUROPE Austria: Kirchengast & Steiner 2001; Britain: Habbukuk 1926* LATIN AMERICA Dominican Republic: MV Flinn et al. 1999:469*; Gabbard & Tandy 1988:155
Females weight more				OCEANIA Australia: Magarey et al. 1999:140 (age 11); New Zealand: EC Rush et al. 2003:3; Philippines: Bobbit in TB Robertson 1923:501*

1.2.1.4b. Weight among Human Adolescents and Adults

Among adolescents and adults, numerous studies show that males weigh more except in early-to-middle adolescents, when the findings have been inconsistent (Split-Table 1.2.1.4b). This presumably reflects the fact that females begin puberty a year or two earlier than do males.

Split-Table 1.2.1.4b. Weight among human adolescents and adults.

Nature of Any Difference	Postpubertal			Multiple Age Categories
	Early-to-Mid Adolescent	Late Adolescent	Adult	
Males weigh more	<p>ASIA <i>Japan</i>: Miwa in JA Robertson 1923:501*</p> <p>EUROPE <i>Italy</i>: Pagliani in Robertson 1923:501*</p> <p>NORTH AMERICA <i>United States</i>: Holt in TB Robertson 1923:500*; Porter in TB Robertson 1923:500*; Holt & McIntosh 1953; Perry et al.2001:2992*</p> <p>OCEANIA <i>Australia</i>: Magarey et al. 1999:140 (age 15)</p>	<p>ASIA <i>Japan</i>: Miwa in JA Robertson 1923:501*; Kouda et al. 2003:1107*</p> <p><i>Philippines</i>: Bobbit in TB Robertson 1923:501*</p> <p>EUROPE <i>Italy</i>: Pagliani in Robertson 1923:501*</p> <p>LATIN AMERICA <i>Dominican Republic</i>: MV Flinn et al. 1999:469*</p> <p>MIDDLE EAST <i>Turkey</i>: Tan et al. 2003:1352</p> <p>NORTH AMERICA <i>Canada</i>: AM Thompson et al. 2003:1686*; <i>United States</i>: GM West 1893*; JA Gilbert 1893:91; JA Gilbert 1897*</p>	<p>ASIA <i>China</i>: Lei et al. 2004:73 (elderly); <i>Japan</i>: Miwa in JA Robertson 1923:501*</p> <p>EUROPE <i>Austria</i>: Kofler & Poustka 2004:2125; <i>Britain</i>: AH Baker & Wardle 2003:271; <i>Denmark</i>: AN Pedersen et al. 2002 (elderly, 80 year olds); <i>Finland</i>: Geelen et al. 2002:1403; <i>France</i>: Ochala et al. 2004:442 (elderly); <i>Germany</i>: G Shan & Bohn 2003* (young); <i>Italy</i>: Perissinotto et al. 2002; <i>Netherlands</i>: Stolck et al. 1996:314 (elderly); Rietveld et al. 2004:196; <i>Several European Countries</i>: de Groot et al. 1991</p> <p>NORTH AMERICA <i>Canada</i>: Ledoux et al. 1997; Marliss et al. 2000:458 (young); <i>United States</i>: RL Jackson & Kelly 1945; Gavan & Swindler 1966; Katch & Weltman 1975; P Freedson et al. 1979; Comuzzie et al. 1993:730 (Mexican Americans); Kwo et al. 1998:1554 (young); al' Absi et al. 1999:334; Pritzlaff et al. 1999; AS Jackson et al. 2002:791; Treiber et al. 2002:709; Karasik et al. 2003:311; Koertge et al. 2003:1320 (CAD patients); G Shan & Bohn 2003* (young); Marczinski et al. 2005:388; Nicolay & Walker 2005:607</p> <p>OCEANIA <i>Australia</i>: A Wright et al. 2002:286 (young); <i>New Guinea</i>: Ulijaszek 1993</p>	<p>EUROPE <i>Britain</i>: RR Baker & Bellis 1993:872</p> <p><i>Scotland</i>: Der et al. 1999:274;</p> <p><i>Sweden</i>: Kuskowska-Wolk et al. 1991</p> <p>NORTH AMERICA <i>United States</i>: Loepky et al. 2000</p> <p>HOMINID <i>Australopithecus</i>: McHenry 1986; McHenry 1991; BG Richmond & Jungers 1995; Lockwood et al. 1996</p>
No signif. difference	<p>ASIA <i>Japan</i>: Kouda et al. 2003:1107*;</p> <p>Kouda et al. 2004:80</p> <p>EUROPE <i>Sweden</i>: Key in TB Robertson 1923:501*</p> <p>NORTH AMERICA <i>Canada</i>: AM Thompson et al. 2003:1686* <i>United States</i>: Roche & Malina 1983:204*</p>			
Females weigh more	<p>EUROPE <i>Britain</i>: Habbukuk 1926*</p> <p>NORTH AMERICA <i>Canada</i>: F Boas & Wissler 1897*; <i>United States</i>: GM West 1893*; JA Gilbert 1897*; FW Smedley 1902:115; F Boas & Wissler 1897*; McNemar & Terman 1936:24*</p>			

1.2.1.5. Weight, Individual Variability in

One study was located pertaining to sex differences in variability in weight and reported that males exhibited greater intra-sex variability than do females (Table 1.2.1.5).

Table 1.2.1.5. Weight, individual variability in.

Nature of Any Difference	Postpubertal		
			Adult
Males more			<p>NORTH AMERICA <i>Canada</i> Marliss et al. 2000:458 (young)</p> <p>INTERNATIONAL <i>Multiple Countries</i>: Archer & Mehdikhani 2003 (meta-analysis)</p> <p>INSECT <i>Seaweed Fly</i>: Wilcockson et al. 1995</p>
No signif. Difference			
Females more			

1.2.1.6. Weight/Body Size Among Non-Primates

An enormous number of studies have assessed the weight and/or body size (or body mass) differences between males and females among non-human species, nearly all of which were limited to full-grown adults. Because of the volume of studies, the findings are summarized in a series of split tables (Split-Tables 1.2.1.6a through 1.2.1.6e).

1.2.1.6a. Weight/Body Size Among Invertebrates and Amphibians

The first of these tables (Split-Table 1.2.1.6a) pertains to invertebrates and amphibians. The one study of an insect species found males to be larger. In the case of amphibians, all of the evidence on salamanders found females to be larger than males.

Table 1.2.1.6a. Weight/body size among invertebrates and amphibians.

Nature of Any Difference	Postpubertal			
				Adult
Males heavier/larger				INSECT <i>Seaweed Fly</i> : Wilcockson et al. 1995
No signif. difference				
Females heavier/larger				AMPHIBIAN <i>Salamander</i> : Valdovieso & Tamsitt 1965 (Adspersa salamander); Vial 1968 (Subpalmata salamander); Hauck 1977a (2 of 2 species); Houck 1977b (10 of 10 species); McCranie & Wilson 1993 (4 of 4 salamander species); McCranie et al. 1996 (Dofleini salamander); Wake 1996 (Gabrieli salamander); RC Bruce 1997 (Colonnea salamander); RC Bruce 1999 (Picadai salamander)

1.2.1.6b. Weight/Body Size Among Birds

Split-Table 1.2.1.6b pertains to birds. Among these groups of animals, the findings have been quite mixed. In about half of all species, adult females were found to be larger, while males were larger in about one-fourth of the species, and no significant sex difference was documented in the remaining one-fourth.

Split-Table 1.2.1.6b. Weight/body size among birds.

Nature of Any Difference	Postpubertal			
				Adult
Males heavier/larger				BIRD <i>Atlantic Puffin</i> : Cramp 1985; <i>Black-Bellied Sandgrouse</i> : Cramp 1985; <i>Black-Winged Stilt</i> : Cramp & Simmons 1983; Marchant & Higgins 1993; Szekely & Reynolds 1995; <i>Buff-Breasted Sandpiper</i> : Pitelka et al. 1974; Cramp & Simmons 1983; Jehl & Murray 1986; <i>Bush Stone-Curlew</i> : Marchant & Higgins 1993; Szekely & Reynolds 1995; <i>Common Guillemont</i> : Cramp 1985; <i>Great Bustard</i> : Raihani et al. 2006; <i>Great Reed Warbler</i> : Westerdahl et al. 2000; <i>Herring Gull</i> : Cramp & Simmons 1983; <i>Pectoral Sandpiper</i> : Pitelka et al. 1974; Cramp & Simmons 1983; Jehl & Murray 1986; Szekely & Reynolds 1995; <i>Sharp-tailed Sandpiper</i> : Pitelka et al. 1974; Johnsgard 1981; Cramp & Simmons 1983; Colston & Burton 1988; Szekely & Reynolds 1995; <i>Red-Winged Blackbird</i> : Weatherhead & Teather 1991; <i>Ruff</i> : Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Snowy Shearbill</i> : Marchant & Higgins 1993; Szekely & Reynolds 1995; <i>Spur-Winged Plover</i> : Walters 1982; Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Yellow-Headed Blackbird</i> : CB Patterson et al. 1980
No signif. difference				BIRD <i>Australian Pratincole</i> : Higgins & Davies 1996; <i>Baird's Sandpiper</i> : Pitelka et al. 1974; Cramp & Reynolds 1983; Jehl & Murray 1986; Szekely & Reynolds 1995; <i>Common Tern</i> : Cramp 1985; <i>Curlew Sandpiper</i> : Pitelka et al. 1974; Cramp & Simmons 1983; Jehl & Murray 1986; Szekely & Reynolds 1995; <i>Eastern Collared Pratincole</i> : Jehl & Murray 1986; Szekely & Reynolds 1995; Higgins & Davies 1996; <i>European Golden Plover</i> : Cramp & Simmons 1983; <i>Kentish Ploves</i> : Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Little Gull</i> : Cramp & Simmons 1983; <i>Little Ringed Ploves</i> : JP Myers et al. 1982; Cramp & Simmons 1983; <i>Rufous-necked Stint</i> : Pitelka et al. 1974; Cramp & Simmons 1983; Jehl & Murray 1986; Colton & Burton 1988; Szekely & Reynolds 1995; <i>Spotted Sandpiper</i> : Oring & Lank 1986; Szekely & Reynolds 1995
Females heavier/larger				BIRD <i>American Jacana</i> : Jenni & Collier 1972; ER Blake 1977; Szekely & Reynolds 1995; del Hoyo et al. 1996; <i>American Woodcock</i> : Jehl & Murray 1986; Poole & Gill 1992; Szekely & Reynolds 1995; <i>Comb-crested Jacana</i> : Marchant & Higgins 1993; Szekely & Reynolds 1995; del Hoyo et al. 1996; <i>Common Redshank</i> : Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Common Sandpiper</i> : Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Common Snipe</i> : Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Coucal</i> : Andersson 1995; <i>Bald Eagle</i> : Bortolotti 1986; <i>Black Coucal</i> : Goymann & Wingfield. 2004a; <i>Black Guillemot</i> : S Cramp 1985; <i>Black-tailed Godwit</i> : Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Dunlin</i> : Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Eurasian Woodcock</i> : Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Great Knot</i> : Cramp & Simmons 1983; <i>Great Snipe</i> : Cramp & Simmons 1983; Jehl & Murray 1986; Saether et al. 1986; Szekely & Reynolds 1995; <i>Least Sandpiper</i> : Cramp & Simmons 1983; Poole & Gill 1992; Szekely & Reynolds 1995; <i>Least Seed-snipe</i> : MacLean 1969; Blake 1977; Jehl & Murray 1986; <i>Lesser Florican</i> : Raihani et al. 2006; <i>Long-toed Stint</i> : JP Myers et al. 1982; Cramp & Simmons 1983; PS Tomkovich 1989; <i>Northern Lapwing</i> : Cramp & Simmons 1983; Szekely & Reynolds 1995; Byrkjedal et al. 1997; <i>Oyster Catcher</i> : Cramp & Simmons 1983; Jehl & Murray 1986; Urban et al. 1986; Szekely & Reynolds 1995; <i>Painted Snipe</i> : Cramp & Simmons 1983; Marchant & Higgins 1993; Szekely & Reynolds 1995; <i>Plains Wanderer</i> : Marchant & Higgins 1993; Szekely & Reynolds 1995; <i>Purple Sandpiper</i> : Cramp & Simmons 1983; Jehl & Murray 1986; Colston & Burton 1988; Szekely & Reynolds 1995; <i>Red Knot</i> : Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Red-necked Phalarope</i> : Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Rock Sandpiper</i> : Prater et al. 1977; Myers et al. 1982; Dunning 1993; <i>Ruddy Turnstone</i> : Cramp & Simmons 1983; Jehl & Murray 1986; Szekely & Reynolds 1995; <i>Sanderling</i> : Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Semipalmated Sandpiper</i> : Pitelka et al. 1974; Cramp & Simmons 1983; Jehl & Murray 1986; Colston & Burton 1988; Szekely & Reynolds 1995; <i>South Polar Skua</i> : Higgins & Davies 1996; <i>Spotted Sandpiper</i> : Cramp & Simmons 1983; Jehl & Murray 1986; Oring & Lank 1986; Szekely & Reynolds 1995; <i>Stilt Sandpiper</i> : Jehl 1973; Pitelka et al. 1974; Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Sub-Antarctic Snipe</i> : Szekely & Reynolds 1995; Higgins & Davies 1996; <i>Surfbird</i> : Pool & Gill 1992; del Hoyo et al. 1996; <i>Western Curlew</i> : Cramp & Simmons 1983; Szekely & Reynolds 1995; <i>Western Sandpiper</i> : Pitelka et al. 1974; Cramp & Simmons 1983; Jehl & Murray 1986; Colton & Burton 1988; Szekely & Reynolds 1995; Higgins & Davies 1996; <i>White-rumped Sandpiper</i> : WRB Oliver 1955; Cramp & Simmons 1983; Poole & Gill 1992; Szekely & Reynolds 1995

1.2.1.6c. Weight/Body Size Among Marsupials.

In the vast majority of adult marsupial species, males exceed the weight or body size of females. Only in a few species were no significant sex differences found (Split-Table 1.2.1.6c).

Split-Table 1.2.1.6c. Weight/body size among marsupials.

Nature of Any Difference	Postpubertal	
	Infant	Adult
Males heavier/larger		MARSUPIAL <i>Agile Wallaby</i> : Strahan 1983; Jarman 1991*; <i>Antilopine Wallaroo</i> : Strahan 1983; Jarman 1991*; <i>Black-striped Wallaby</i> : Strahan 1983; <i>Eastern Gray Kangaroo</i> : Strahan 1983; Jarman 1991*; <i>Gray Short-Tail Opossum</i> : Kraus & Fadem 1987; <i>Lumholtz's Tree Kangaroo</i> : Strahan 1983; Jarman 1991*; <i>Nail-Tailed Wallaby</i> : Strahan 1983; <i>Parma Wallaby</i> : Strahan 1983; Jarman 1991*; <i>Red-Bellied Pademelon</i> : Strahan 1983; Jarman 1991*; <i>Red Kangaroo</i> : Strahan 1983; Jarman 1991*; <i>Red-Legged Pademelon</i> : Strahan 1983; Jarman 1991*; <i>Red-Necked Pademelon</i> : Strahan 1983; Jarman 1991*; <i>Red-Necked Wallaby</i> : Strahan 1983; Jarman 1991*; <i>Swamp Wallaby</i> : Strahan 1983; <i>Tammar Wallaby</i> : Strahan 1983; Jarman 1991*; <i>Western Gray Kangaroo</i> : Strahan 1983; Jarman 1991*; <i>Whiptail Wallaby</i> : Strahan 1983; Jarman 1991*
No signif. difference		MARSUPIAL <i>Little Rock Wallaby</i> : Strahan 1983; Jarman 1991*; <i>Rock Wallaby</i> : Strahan 1983; Jarman 1991*; <i>Western Brush Wallaby</i> : Strahan 1983; Jarman 1991*
Females heavier/larger		

1.2.1.6d. Weight/Body Size Among Mammals Other Than Ungulates and Primates

As shown in Split-Table 1.2.1.6d, among most species of mammals other than ungulates and primates, males are larger than females, at least in adulthood.

Split-Table 1.2.1.6d. Weight/body size among mammals other than ungulates and primates.

Nature of Any Difference	Prepubertal		Postpubertal	
	Infant	Adult	Infant	Adult
Males heavier/larger				CANINE <i>Dog</i> : JP Scott & Fuller 1965:329 MUSTELID <i>African Clawless Otter</i> : Kingdon 1971; <i>African Striped Weasel</i> : Estes 1991; <i>American Badger</i> : Messick & Hornocker 1981; <i>American Mink</i> : JL Mitchell 1961; Banfield 1974; <i>American Pine Marten</i> : Banfield 1974; <i>Black-footed Ferret</i> : Anderson et al. 1986; <i>Canadian River Otter</i> : Banfield 1974; Stephenson 1977; <i>Ermine</i> : Ridgeway & Harrison 1981; <i>European Pine Marten</i> : Ridgeway & Harrison 1981; <i>European Polecat</i> : Ridgeway & Harrison 1981; <i>European River Otter</i> : Corbet & Harris 1991; <i>Fisher</i> : Wright & Coulter 1967; Banfield 1974; <i>Giant Otter</i> : Duplaise 1980; <i>Hog-nosed Skunk</i> : van Gelder 1968; <i>Least Weasel</i> : Ridgeway & Harrison 1981; <i>Long-tailed Weasel</i> : Brown & Lasiewski 1972; Banfield 1974; <i>Old World Badger</i> : Ridgeway & Harrison 1981; <i>Sea Otter</i> : Ridgeway & Harrison 1981; <i>Striped Polecat</i> : Estes 1991; <i>Striped Skunk</i> : Verts 1967; <i>Wolverine</i> : Rausch & Pearson 1972 PINNIPED <i>Australian Sea Lion</i> : Ridgeway & Harrison 1981; <i>Bearded Seal</i> : Bonner 1990; <i>California Sea Lion</i> : Ridgeway & Harrison 1981; FE Fish et al. 2003; <i>Elephant Seal</i> : Le Boeuf & Reiter 1988; Slip et al. 1994; Le Boeuf et al. 2000; <i>Galapagos Fur Seal</i> : Trillmich 1987; <i>Gray Seal</i> : Corbet & Harris 1991; Mohn & Bowen 1996; CA Beck et al. 2003:781 (length & weight); <i>Harbor Seal</i> : Corbet & Harris 1991; Coltman et al. 1997; WD Bowen et al. 1999; <i>New Zealand Sea Lion</i> : Ridgeway & Harrison 1981; <i>Northern Elephant Seal</i> : Bonner 1990; <i>Northern Fur Seal</i> : Banfield 1974; <i>Ringed Seal</i> : Bonner 1990; <i>Ross Seal</i> : Bonner 1990; <i>Southern Elephant Seal</i> : Bonner 1990; <i>Southern Fur Seal</i> : Ridgeway & Harrison 1981; <i>Southern Sea Lion</i> : Renouf 1994; <i>Spotted Seal</i> : Bonner 1990; <i>Steller's Sea Lion</i> : Ridgeway & Harrison 1981; <i>Walrus</i> : Corbet & Harris 1991 PROBOSID <i>African Elephant</i> : Laws et al. 1975; <i>Asian Elephant</i> : Sukumar 1989 RODENT <i>Coypu</i> : Gasling 1986; <i>Mouse</i> : Wiedmer et al. 2004:2861; <i>Rat</i> : HD King 1915 (body size); Leshner & Collier 1973; Li & Lumeng 1984; Beaston-Wimmer & Smolen 1991; Jankala et al. 2005 (weight); Piano et al. 2005
No signif. difference	PINNIPED <i>Elephant Seal</i> : Bell et al. 1997 (first year of life) RODENT <i>Rat</i> : Beaston-Wimmer & Smolen 1991*(postnatal day 1)			MUSTELID <i>Honey Badger</i> : RD Estes 1991 PINNIPED <i>Baikal Seal</i> : Bonner 1990; <i>Caspian Seal</i> : Bonner 1990; <i>Harp Seal</i> : Bonner 1990; <i>Ribbon Seal</i> : Bonner 1990 RODENT <i>Skuas</i> : Furness 1987; Kalmbach et al. 2001
Females heavier/larger				PINNIPED <i>Hawaiian Monk Seal</i> : Bonner 1990; <i>Leopard Seal</i> : Bonner 1990; <i>Mediterranean Monk Seal</i> : Bonner 1990; <i>Weddell Seal</i> : Bryden et al. 1984; Bonner 1990 RODENT <i>Hamster</i> : K Kowalewski 1969 (weight)

1.2.1.6e. Weight/Body Size Among Ungulates

In the case of ungulates, males have been found to be larger than females on average in nearly all species (Split-Table 1.2.1.6e).

Split-Table 1.2.1.6e. Weight/body size among ungulates.

Nature of Any Difference	Postpubertal	
		Adult
Males heavier/larger		<p>UNGULATE <i>African Buffalo</i>: Georgiadis 1985; Estes 1991; <i>American Bison</i>: Berger & Peacock 1988; <i>Axis Deer</i>: Strahan 1983; <i>Barbary Sheep</i>: Simpson 1980; <i>Big Horn Sheep</i>: DA Blood et al. 1970; Ruckstuhl 1998; <i>Bison</i>: Van Vuren 1983; Krosinska et al. 1987; <i>Black Wildebeest</i>: Georgiadis 1985; Estes 1991; <i>Blacktail Deer</i>: Bowyer et al. 1996; <i>Bluebuck</i>: WJ Sheffield 1983; <i>Blue Sheep</i>: MK Oli 1994; <i>Bongo</i>: Estes 1991; <i>Brow-antlered Deer</i>: Geist & Bayer 1988; Putman 1988; <i>Bush Buck</i>: Georgiadis 1985; Estes 1991; <i>Caribou</i>: TK Fuller & Keith 1981; <i>Chamois</i>: J Kingdon 1971; Lovari & Cosentino 1986; <i>Chinese Water Deer</i>: Corbet & Harris 1991; <i>Common Eland</i>: Georgiadis 1985; Estes 1991; <i>Dall's Sheep</i>: Bunnell & Olsen 1976; <i>Deer</i>: Eloranta & Nieminen 1986; Kojola 1989:183; <i>Domestic Sheep</i>: Corbet & Harris 1991; <i>Elk</i>: Bender & Haufler 1996; <i>Fallow Deer</i>: Corbet & Harris 1991; <i>Gaur</i>: Owen-Smith 1988; <i>Gemsbock</i>: Estes 1991; <i>Gerenuk</i>: Kingdon 1971; Estes 1991; <i>Giraffe</i>: Estes 1991; Ginnett & Demment 1997; <i>Grant's Gazelle</i>: Georgiadis 1985; Estes 1991; <i>Greater Kudu</i>: Georgiadis 1985; Estes 1991; <i>Hartebeest</i>: Kingdon 1971; Estes 1991; <i>Hog Deer</i>: Putman 1988; Dhungel & O'Gara 1991; <i>Impala</i>: J Kingdon 1971; RD Estes 1991; <i>Kob</i>: Georgiadis 1985; Estes 1991; <i>Lechwe</i>: Georgiadis 1985; Estes 1991; <i>Lesser Kudu</i>: Georgiadis 1985; Estes 1991; <i>Moose</i>: Miquelle 1991; Miquelle et al. 1992; Molvar & Bowyer 1994; <i>Mouflon</i>: Bon et al. 1992; <i>Mountain Goat</i>: Banfield 1974; <i>Mountain Sheep</i>: Bleich et al. 1997; <i>Mule Deer</i>: Anderson et al. 1974; <i>Musk Deer</i>: Putman 1988; <i>Musk Ox</i>: DR Gray 1973; PB Latour 1987; Heard 1992; <i>Nyala</i>: Georgiadis 1985; Estes 1991; <i>Pere David's Deer</i>: Beck & Wemmer 1983; <i>Pronghorn</i>: GJ Mitchell 1971; Byers et al. 1994; <i>Pronghorn Sheep</i>: Kitchen 1974; <i>Puku</i>: Kingdon 1971; Estes 1991; <i>Red Deer</i>: Flook 1970; Clutton-Brock et al. 1982; <i>Reed Buck</i>: Kingdon 1971; Estes 1991; <i>Reindeer</i>: Anderson et al. 1974; Leader-Williams 1988; <i>Road Antelope</i>: Georgiadis 1985; Estes 1991; <i>Roe Deer</i>: Corbet & Harris 1991; NG Chapman et al. 1993; Danilkin 1996; <i>Sable Antelope</i>: Georgiadis 1985; Estes 1991; <i>Saiga</i>: Bannikov 1961; <i>Sambar Deer</i>: Strahan 1983; <i>Sika Deer</i>: Corbet & Harris 1991; <i>Sitatunga</i>: Estes 1991; <i>Soay Sheep</i>: Perez-Barberia & Gordon 1999:260; <i>Sprngbok</i>: Georgiadis 1985; RD Estes 1991; <i>Sunda Samba</i>: Strahan 1983; <i>Tahr</i>: CM King 1990; <i>Thomson's Gazelle</i>: N Georgiadis 1985; RD Estes 1991; <i>Topi</i>: Georgiadis 1985; Estes 1991; <i>Water Buck</i>: Kingdon 1971; Estes 1991; <i>Whitetail Deer</i>: Hirth 1977; McCullough 1979; Lagory 1986; Leberg et al. 1992; <i>Wild Goat</i>: GB Schaller 1979; O'Brien 1984; <i>Wild Sheep</i>: Grubb 1974</p>
No signif. difference		<p>UNGULATE <i>Beira Antelope</i>: RD Estes 1991; RM Nowak 1991; <i>Brochet Deer</i>: Geist & Bayer 1988; Putman 1988; <i>Duiker Antelope</i>: J Kingdon 1971; RD Estes 1991; <i>Gray Duiker</i>: Georgiadis 1985; RD Estes 1991; <i>Klipspringer Antelope</i>: RIM Dunbar 1990; RD Estes 1991; <i>Rhebok Antelope</i>: Owen-Smith 1988; <i>Serow</i>: H.Soma 1987; <i>Steenbok Antelope</i>: J Kingdon 1971; RD Estes 1991</p>
Females heavier/larger		<p>UNGULATE <i>Barking Deer</i>: Corbet & Harris 1991; <i>Bates Dwarf Antelope</i>: Kingdon 1971; RD Estes 1991; <i>Dik Dik</i>: Kingdon 1971; RD Estes 1991; <i>Oribi</i>: Kingdon 1971; RD Estes 1991</p>

1.2.1.7. Weight/Body Size Among Primates Except Humans

Given the very large number of studies of sex differences in the adult body size of primates, the ensuing table is split into the following groupings: apes, prosimians, African primates other than apes, Asiatic primates other than apes, New World primates. With respect to sex differences in body size among most species of primates, males are larger. This generalization was also reached by a study of 53 species of primates by Leutenegger (1982). He reported that in 45 species males were larger, in 3 species females were larger, and in five species there was no significant difference.

1.2.1.7a. Weight/Body Size among Apes

Apes are indigenous to Africa and southern Asia. Split-Table 1.2.1.7a shows that in all but a few species of the so-called lesser apes the findings have been very consistent in indicating that males are larger on average than females.

Split-Table 1.2.1.7a. Weight/body size among apes.

Nature of Any Difference	Postpubertal	
		Adult
Males heavier/larger		<p>APE <i>Agile Gibbon</i>: van den Berghe 1973; Gaulin & Sailer 1984; Payne & Francis 1985; <i>Chimpanzee</i>: Gavan & Swindler 1966; Fedigan 1982:55; Estes 1991; Watts & Pusey 1993; <i>Gorilla</i>: Gavan & Swindler 1966; Napier & Napier 1967*; Gijzen & Tijskens 1971; Scollay et al. 1975; Harvey & Clutton-Brock 1985; Jungers 1985; Fleagle 1988; Estes 1991; <i>Orangutan</i>: Napier & Napier 1967*; DeSilva 1971; Mackinnon 1974; HD Rijksen 1975; Harvey & Clutton-Brock 1985; Jungers 1985; Watts & Pusey 1993; <i>Siamang</i>: Leufenegger & Cheverud 1982; Gaulin & Sailer 1984; <i>Silvery Javan Gibbon</i>: Harvey & Clutton-Brock 1985; <i>White-Browed Gibbon</i>: Leufenegger & Cheverud 1982; Harvey & Clutton-Brock 1985; <i>White-Handed Gibbon</i>: Napier & Napier 1967*; Roonwal & Mohnot 1977; Gaulin & Sailer 1984</p>
No signif. difference		<p>APE <i>Siamang Ape</i>: Fedigan 1982:54*</p>
Females heavier/larger		<p>APE <i>Black Gibbon</i>: Harvey & Clutton-Brock 1985; <i>Kolss' Gibbon</i>: Harvey & Clutton-Brock 1985</p>

1.2.1.7b. Weight/Body Size among Prosimians

Prosimians are the descendants of most primitive appearing primates. According to Split-Table 1.2.1.7b, prosimians tend to be almost evenly divided between species in which there are no significant gender differences in body size and those in which males are larger.

Split-Table 1.2.1.7b. Weight/body size among prosimians.

Nature of Any Difference	Postpubertal	
		Adult
Males heavier/larger		PROSIMIAN IN MADAGASCAR & AFRICA <i>Bushbaby</i> : Chiarelli 1972; <i>Coquerel's Mouse Lemur</i> : Kappeler 1997; <i>Fork-marked Lemur</i> : Harvey & Clutton-Brock 1985; <i>Garnett's Greater Bush Baby</i> : Bearder 1987; <i>Gentle Lemur</i> : Jorde & Spuhler 1974; <i>Golden Potto</i> : Gaulin & Sailer 1984; <i>Hairy-eared Lemur</i> : Kappeler 1991; <i>Lesser Bush Baby</i> : GA Doyle 1974; <i>Northern Lesser Bush Baby</i> : Harvey & Clutton-Brock 1985; Bearder 1987; Kappeler 1990; <i>Potto</i> : Gaulin & Sailer 1984; <i>Purple-Faced Langur</i> : Napier & Napier 1967*; Napier 1985; <i>Pygmy Loris</i> : Kappeler 1991; <i>Ring-Tailed Lemur</i> : Gaulin & Sailer 1984; <i>Ruffed Lemur</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; <i>Slender Loris</i> : Napier & Napier 1967*; Gaulin & Sailer 1984; <i>Slow Loris</i> : Napier & Napier 1967*; Harvey & Clutton-Brock 1985; Kappeler 1990; Kappeler 1991; <i>Thick-tailed Lesser Bush Baby</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; Kappeler 1991; <i>Verreaux's Sifaka</i> : GA Doyle 1979; Gaulin & Sailer 1984; Kappeler 1991; PC Wright 1999
No signif. difference		PROSIMIAN IN MADAGASCAR & AFRICA <i>Black Lemur</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; Kappeler 1991; Wright 1999; <i>Brown Lemur</i> : Gaulin & Sailer 1984; <i>Cocquerel's Mouse Lemur</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; <i>Diademed Sifaka</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; <i>Fat-tailed Dwarf Lemur</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; Fietz 1999a; <i>Gray Mouse Lemur</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; <i>Greater Dwarf Lemur</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; <i>Indri</i> : Gaulin & Sailer 1984; <i>Lesser Bamboo Lemur</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; Kappeler 1991; <i>Mongoose Lemur</i> : Gaulin & Sailer 1984; Kappeler 1991; <i>Mouse Lemur</i> : Fietz 1998; Fietz 1999b; <i>Red-tailed Sportive Lemur</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; <i>Ringtail Lemur</i> : Jorde & Spuhler 1974; <i>Sifaka</i> : Jorde & Spuhler 1974; <i>Southern Needle-clawed Bush Baby</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; Kappeler 1991; <i>Verreaux's Sifaka</i> : Kraus et al. 1999; Lawler et al. 2005; <i>Weasel Sportive Lemur</i> : Gaulin & Sailer 1984; <i>Wolly Lemur</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; Mittermeier et al. 1994; Wright 1999
Females heavier/larger		PROSIMIAN IN MADAGASCAR <i>White-footed Sportive Lemur</i> : Kappeler 1991

1.2.1.7c. Weight/Body Size Among African Primates Other Than Apes

Nearly all studies of sex differences in the body size of African primates have concluded that males are larger than females (Split-Table 1.2.1.7c).

Split-Table 1.2.1.7c. Weight/body size among African primates other than apes.

Nature of Any Difference	Postpubertal	
		Adult
Males heavier/larger		AFRICAN PRIMATE (EXCEPT APE) <i>Agile Mangabey</i> : Groves 1989; <i>Allen's Swamp Monkey</i> : Gautier-Hion 1988a; <i>Black Colobus</i> : Harvey & Clutton-Brock 1985; Estes 1991; <i>Black & White Colobus</i> : JF Oates 1977; <i>Blue Monkey</i> : Coelho 1974; Napier 1981; Gaulin & Sailer 1984; Estes 1991; <i>Campbell's Guenon</i> : Napier 1981; Oates et al. 1990; <i>Chacma Baboon</i> : Harvey et al. 1987; Estes 1991; <i>Common Baboon</i> : Jorde & Spuhler 1974; <i>Drill</i> : Harvey & Clutton-Brock 1985; Harvey et al. 1987; Estes 1991; <i>Eastern Black-and-white Colobus</i> : Oates et al. 1994; Harvey & Clutton-Brock 1985; Estes 1991; <i>De Brazza's Monkey</i> : Napier 1981; Gaulin & Sailer 1984; Estes 1991; <i>Diana Monkey</i> : Oates et al. 1990; <i>Gelada Baboon</i> : Fedigan 1982:55; Fleagle 1988; Estes 1991; <i>Gray-Cheeked Mangabey</i> : Napier 1981; Gaulin & Sailer 1984; Estes 1991; <i>Greater Spot-Nosed Guenon</i> : Harvey & Clutton-Brock 1985; Estes 1991; <i>Guinea Baboon</i> : Harvey & Clutton-Brock 1985; <i>Hamadryas Baboon</i> : Harvey & Clutton-Brock 1985; Estes 1991; Kummer 1995; <i>Lesser Spot-Nosed Guenon</i> : Napier 1981; Oates et al. 1990; <i>L'Hoest's Monkey</i> : Harvey & Clutton-Brock 1985; H Gervaearts 1992; M Colyn 1994; <i>Mandrill Baboon</i> : Schultz 1956; Napier & Napier 1967*; Jouventin 1975; Harvey & Clutton-Brock 1985; Fleagle 1988; Estes 1991; <i>Mona Monkey</i> : Harvey & Clutton-Brock 1985; Glenn & Bensen 1998; <i>Mustached Guenon</i> : Gaulin & Sailer 1984; Fleagle 1988; Estes 1991; <i>Olive Baboon</i> : Napier 1981; Estes 1991; <i>Olive Colobus</i> : Oates et al. 1994; <i>Owl-Faced Monkey</i> : Gevaerts 1992; Colyn 1994; <i>Patas Monkey</i> : Fedigan 1982:54; Harvey & Clutton-Brock 1985; <i>Pennant's Red Colobus</i> : Oates et al. 1994; <i>Red Colobus</i> : Struhsaker 1969; <i>Red-Tailed Guenon</i> : Napier & Napier 1967*; Napier 1981; <i>Sclater's Guenon</i> : Oates et al. 1992; <i>Sooty Mangabey Monkey</i> : Jorde & Spuhler 1974; Oates et al. 1990; <i>Sun-Tailed Guenon</i> : Gautier-Hion 1988b; <i>Talapoin Monkey</i> : Gautier-Hion 1975; Gaulin & Sailer 1984; Estes 1991; <i>Tana River Mangabey</i> : Napier 1981; Gaulin & Sailer 1984; Estes 1991; <i>Western Red Colobus</i> : Harvey & Clutton-Brock 1985; Estes 1991; Oates et al. 1994; <i>White-Collared Mangabey</i> : Harvey & Clutton-Brock 1985; Estes 1991; <i>White-Thighed Black-and-White Colobus</i> : Oates et al. 1994; <i>Wolf's Guenon</i> : Gevaerts 1992; Colyn 1994; <i>Yellow Baboon</i> : Napier 1981; Harvey & Clutton-Brock 1985
No signif. difference		AFRICAN PRIMATE (EXCEPT APE) <i>Allen's Bush Baby</i> : Gaulin & Sailer 1984; Kappeler 1990; <i>Aye Aye</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; Kappeler 1991; <i>Demidoff's Bush Baby</i> : Gaulin & Sailer 1984; Kappeler 1990; Kappeler 1991; <i>Talapoin Monkey</i> : A Segre 1970; <i>Temminck's Red Colobus</i> ; ED Sarin 1994
Females heavier/larger		

1.2.1.7d. Weight/Body Size Among Asiatic Primates Other Than Apes

Primates that are indigenous to Asia, including numerous islands that extend into the Indian Ocean, have been investigated extensively regarding sex differences in body size. Nearly all of these studies have concluded that the body size of males surpasses that of females (Split-Table 1.2.1.7d).

Split-Table 1.2.1.7d. Weight/body size among Asiatic primates other than apes.

Nature of Any Difference	Postpubertal	
		Adult
Males heavier/larger		ASIATIC/INDIAN OCEAN PRIMATE <i>Assamese Macaque</i> : Smith & Jungers 1997; <i>Barbary Macaque</i> : M Fa 1989; Smith & Jungers 1997; <i>Bonnet Macaque</i> : Napier & Napier 1967*; M Fa 1989; Smith & Jungers 1997; <i>Capped Leaf Monkey</i> : Gaulin & Sailer 1984; Oates et al. 1994; <i>Celebes Macaque</i> : Napier & Napier 1967*; <i>Crab-Eating Macaque</i> : Napier & Napier 1967*; <i>Crested Black Macaque</i> : Smith & Jungers 1997; <i>Formosan Macaque</i> : Leufenegger & Cheverud 1982; Smith & Jungers 1997; <i>Golden Langur</i> : Harvey & Clutton-Brock 1985; Oates et al. 1994; <i>Hanuman Langur</i> : Napier & Napier 1967*; Gaulin & Sailer 1984; Oates et al. 1994; <i>Hose's Leaf Monkey</i> : Fleagle 1988; JF Oates et al. 1994; <i>Japanese Macaque</i> : Masui et al. 1973; Fedigan 1982:55; Gaulin & Sailer 1984; M Fa 1989; Schaik et al. 1992; <i>Lion-Tailed Macaque</i> : Silk & Boyd 1983; Harvey & Clutton-Brock 1985; Fa 1989; <i>Long-Tailed Macaque</i> : Bernstein 1970; Silk & Boyd 1983; Gaulin & Sailer 1984; Wrangham et al. 1993; <i>Maroon Leaf Monkey</i> : Harvey & Clutton-Brock 1985; van Schaik et al. 1992; Oates et al. 1994; <i>Mitered Leaf Monkey</i> : Gaulin & Sailer 1984; Harvey & Clutton-Brock 1985; Oates et al. 1994; <i>Moor Macaque</i> : Silk & Boyd 1983; Harvey & Clutton-Brock 1985; <i>Nilgiri Langur</i> : Fedigan 1982:55; Gaulin & Sailer 1984; Harvey & Clutton-Brock 1985; Napier 1985; <i>Phayre's Leaf Monkey</i> : Napier 1985; <i>Philippine Tarsier</i> : Harvey & Clutton-Brock 1985; Kappeler 1990; <i>Pigtail Langur</i> : JG Fleagle 1988; JF Oates et al. 1994; <i>Pigtail Macaque</i> : Napier & Napier 1967*; Bernstein 1970; Silk & Boyd 1983; Harvey & Clutton-Brock 1985; Fa 1989; <i>Red-shanked Douc Langur</i> : Fleagle 1988; <i>Proboscis Monkey</i> : Aldrich-Blake 1979; JA Kern 1964; Napier & Napier 1967*; SJC Gaulin & Sailer 1984; JF Oakes et al. 1994; <i>Rhesus Macaque</i> : Napier & Napier 1967*; JH Kirk 1972; Bernstein 1970; Silk & Boyd 1983; Rawlins et al. 1984; Harvey & Clutton-Brock 1985; M Fa 1989; SMS Schwartz & Kemnitz 1992; <i>Silvered Langur</i> : Oates et al. 1994; <i>Spectacled Leaf Monkey</i> : Harvey & Clutton-Brock 1985; Napier 1985; van Schaik et al. 1992; <i>Stump-Tailed Macaque</i> : Chevalier-Skolnikoff 1975; M Fa 1989; Smith & Jungers 1997; <i>Tibetan Macaque</i> : Smith & Jungers 1997; <i>Tonkean Macaque</i> : Fooden 1969; Smith & Junger 1997; <i>Sichuan Golden Snub-nosed Monkey</i> : NG Jabolonski & Ruliang 1995; <i>Tonkin Snub-nosed Monkey</i> : R Boonratana & Canh 1994; <i>Toque Macaque</i> : W Dittus 1975; Silk & Boyd 1983; Gaulin & Sailer 1984; M Fa 1985; <i>Vervet Monkey</i> : Napier 1981; Fedigan 1982:54; Gaulin & Sailer 1984; Estes 1991; <i>Western Tarsier</i> : Gaulin & Sailer 1984
No signif. difference		ASIATIC/INDIAN OCEAN PRIMATE <i>Mentawai Island Leaf Monkey</i> : Tilson 1980; Gaulin & Sailer 1984; Oates et al. 1994; <i>Spectral Tarsier</i> : Harvey & Clutton-Brock 1985
Females heavier/larger		ASIATIC/INDIAN OCEAN PRIMATE <i>Dian's Tarsier</i> : Tremble et al. 1993; <i>Grizzled Leaf Monkey</i> : Fleagle 1988

1.2.1.7e. Weight/Body Size Among New World Primates

Among the species of primates that are native to Central and South America, males are usually larger than females as adults. Nevertheless, Split-Table 1.2.1.7e shows that there appear to be several exceptions, including some in which the adult weight of females exceeds that of males.

Split-Table 1.2.1.7e. Weight/body size among New World primates.

Nature of Any Difference	Postpubertal	
		Adult
Males heavier/larger		NEW WORLD PRIMATE <i>Bald Uacari</i> : Ford & Davis 1992; Ford 1994; Plavcan & van Schaik 1997; Smith & Jungers 1997; <i>Bare-Ear Marmoset</i> : Ford 1994; <i>Bearded Saki</i> : Ford & Davis 1992; Ford 1994; <i>Black-Faced Saki</i> : Hershkovitz 1987; Ford 1994; <i>Black & Gold Howler Monkey</i> : Ford & Davis 1992; Ford 1994; Leigh 1994; Plavcan & van Schaik 1997; Smith & Jungers 1997; <i>Black-Handed Spider Monkey</i> : Ford & Davis 1992; Ford 1994; Leigh 1994; Plavcan & van Schaik 1997; <i>Black Howler Monkey</i> : SM Ford 1994; <i>Black Mangabey</i> : Napier 1981; <i>Black Squirrel Monkey</i> : Ford 1994; <i>Black Tufted-Eared Marmoset</i> : Ford 1994; <i>Bolivian Squirrel Monkey</i> : Ford 1994; <i>Brown Capuchin</i> : Ford & Davis 1992; Ford 1994; Leigh 1994; Plavcan & van Schaik 1997; Smith & Jungers 1997; <i>Brown Howler Monkey</i> : Ford & Davis 1992; Plavcan & van Schaik 1997; Smith & Jungers 1997; <i>Brown Titi Monkey</i> : Hershkovitz 1990; Ford 1994; <i>Capuchin Monkey</i> : Napier & Napier 1967*; Coelho 1974; <i>Common Marmoset</i> : Ford 1994; <i>Common Squirrel Monkey</i> : Ford 1994; <i>Dusky Titi Monkey</i> : Ford & Davis 1992; Ford 1994; Leigh 1994; Plavcan & van Schaik 1997; <i>Geoffroy's Marmoset</i> : Ford 1994; <i>Golden Backed Squirrel Monkey</i> : Ford 1994; <i>Golden-Handed Tamarin</i> : Ford 1994; <i>Golden Headed Lion Tamarin</i> : Ford 1994; <i>Howler Monkey</i> : BL Pope 1966; Napier & Napier 1967*; <i>Mantled Howler Monkey</i> : Ford & Davis 1992; Ford 1994; Plavcan & van Schaik 1997; Smith & Jungers 1997; <i>Monk Saki</i> : Ford & Davis 1992; Ford 1994; Smith & Jungers 1997; <i>Mustached Tamarin</i> : Ford 1994; <i>Pygmy Marmoset</i> : Ford 1994; <i>Red-Backed Squirrel Monkey</i> : Ford 1994; <i>Red-Handed Howler Monkey</i> : Ford & Davis 1992; Ford 1994; Plavcan & van Schaik 1997; Smith & Jungers 1997; <i>Red Howler Monkey</i> : Ford & Davis 1992; Ford 1994; Plavcan & van Schaik 1997; <i>Snehlages Marmoset</i> : SM Ford 1994; <i>Spider Monkey</i> : Eisenberg & Kuehn 1966; Napier & Napier 1967*; <i>Squirrel Monkey</i> : Jorde & Sphuler 1974; <i>Weeper Capuchin</i> : Ford & Davis 1992; Ford 1994; Plavcan & van Schaik 1997; Smith & Jungers 1997; <i>White-bellied Spider Monkey</i> : SM Ford 1994; <i>White-Faced Saki</i> : Ford & Davis 1992; Ford 1994; Leigh 1994; Plavcan & van Schaik 1997; Smith & Jungers 1997; <i>White-Fronted Capuchin</i> : Ford & Davis 1992; Ford 1994; Leigh 1994; <i>White-Nosed Bearded Saki</i> : Ford & Davis 1992; Ford 1994; <i>White-Throated Capuchin</i> : Ford & Davis 1992; Ford 1994; Smith & Jungers 1997; <i>Woolly Monkey</i> : Ford & Davis 1992; Ford 1994; Leigh 1994; Plavcan & van Schaik 1997; Mith & Jungers 1997; <i>Wooly Spider Monkey</i> : Ford 1994
No signif. difference		NEW WORLD PRIMATE <i>Bare-faced Tamarin</i> : SM Ford 1994; <i>Brown-headed Spider Monkey</i> : SM Ford 1994; <i>Collared Titi Monkey</i> : Kinzey 1981; SM Ford 1994; <i>Common Marmoset</i> : Power et al. 2001; <i>Dusky Titi</i> : Fedigan 1982:54*; <i>Maus Marmoset</i> : Mittermeier et al. 1992; <i>Red-crested Tamarin</i> : SM Ford 1994; <i>Southern Red-necked Monkey</i> : PC Wright 1984; <i>Yellow-Handed Titi</i> : Fedigan 1982:54*
Females heavier/larger		NEW WORLD PRIMATE <i>Black Spider Monkey</i> : SM Ford 1994; SM Ford 1994; <i>Cottontail Tamarin</i> : Napier & Napier 1967; <i>Cotton-top Tamarin</i> : SM Ford 1994; <i>Masked Titi Monkey</i> : Hershkovitz 1990; SM Ford 1994; <i>Northern Gray-necked Owl Monkey</i> : SM Ford 1994; <i>Owl Monkey</i> : Napier & Napier 1967*; <i>Red-handed Tamarin</i> : Napier & Napier 1967*; <i>Red-bellied Tamarin</i> : SM Ford 1994; <i>Red Titi Monkey</i> : Hershkovitz 1990; SM Ford & Davis 1992; SM Ford 1994; RJ Smith & Jungers 1997; <i>Saddleback Tamarin</i> : Napier 1976; SM Ford 1994; <i>Tassel-eared Marmoset</i> : SM Ford 1994

1.2.2. Bodily Proportions

Bodily proportions have to do with ratios of one aspect of the body relative to some other aspect, such as weight relative to height.

1.2.2.1. Body Mass Index (Weight-to-Height Ratio)

Extensive research, as shown in Table 1.2.2.1, has been published regarding gender differences in body mass index (the weight-to-height ratio), the majority of which have involved adult subjects. These studies lead one to an inconsistent conclusion with respect to any differences. Ultimately, the answer may depend upon the population or sub-population being studied.

Table 1.2.2.1. Body mass index (weight-to-height ratio).

Nature of Any Difference	Prepubertal			Postpubertal		Multiple Age Categories
	Infant	Toddler	Childhood	Adolescent	Adult	
Males higher	ASIA China Tam et al. 1999:509*			ASIA China: Li et al. 2005:1140* (early adolescence); Japan: Kouda et al. 2004:80 (young); EUROPE Italy: DeVito et al. 1999:651* NORTH AMERICA Canada: Galambos et al. 2004:20	EUROPE Denmark: Roepstorff et al. 2002:E43b (young); Finland: Lahti-Koski et al. 2001* (young); Geelen et al. 2002:1403; France: Faurie et al. 2004:3 (college); Italy: DeVito et al. 1999:651*; Netherlands: Seidell et al. 1995* (young) Poland: Bielicki et al. 2001:167* (ages 22-40) NORTH AMERICA Canada: Marliss et al. 2000:458 (young); United States: Flegal et al. 1998* (young); al' Absi et al. 1999:334; DiGioacchino et al. 2001* (college, Whites); Karasik et al. 2003:311; Stini 2003:40*	EUROPE Belgium: Moens et al. 1999 (full-time workers); Sweden: Kuskowska-Wolk et al. 1991
No signif. difference	ASIA China Tam et al. 1999:509*		ASIA China: Li et al. 2005:1140* OCEANIA New Zealand: S Williams 2001	NORTH AMERICA United States: Ambrosius et al. 1998:244	ASIA China: Lei et al. 2004:73 (elderly); Taiwan: Hsu et al. 2002:58 EUROPE Britain: AH Baker & Wardle 2003:271; O Evans & Steptoe 2003:765 (medical school); Finland: Lahti-Koski et al. 2001*; Italy: Zamboni et al. 2003:323 (elderly); Netherlands: Seidell et al. 1995*; Stolk et al. 1996:314 (elderly); Poland: Bielicki et al. 2001:167* (ages 41-50); Sweden: Hellstrom et al. 2000:459 NORTH AMERICA United States: BV Howard et al. 1995:393; Flegal et al. 1998*; DiGioacchino et al. 2001* (college, Blacks); AS Jackson et al. 2002:791; Treiber et al. 2002:709; Cnop et al. 2003:461; Stini 2003:40* (elderly); Stranges et al. 2004:951 (middle age/elderly)	EUROPE Belgium: Kornitzer & Bara 1989 NORTH AMERICA Canada: Pascot et al. 2002:401
Females higher			EUROPE Austria: Kirchengast & Steiner 2001 OCEANIA New Zealand: EC Rush et al. 2003:4		EUROPE Denmark: Roepstorff et al. 2002:E43b; Finland: Lahti-Koski et al. 2001* (elderly); Italy: Perissinotto et al. 2002 (elderly); Netherlands: Seidell et al. 1995* (elderly); Poland: Bielicki et al. 2001:167* (ages 51-60) NORTH AMERICA United States: Comuzzie et al. 1993:730 (Mexican Americans); Flegal et al. 1998* (elderly) OCEANIA Australia: Wang & Hoy 2004:510 (aborigines, diabetes sufferers)	EUROPE Britain: Womersley & Durnin 1977; Spain Gutierrez-Fisac et al. 1995 NORTH AMERICA United States: AS Jackson et al. 1980; Deurenberg et al. 1991; Deurenberg et al. 1998; AS Jackson et al. 2002:791

1.2.2.2. Overweight

Most studies of obesity use the body mass index (BMI), which involves converting height and weight to metrics and then dividing one's weight by the square of one's height. The most widely used BMI range for designating a person as overweight is 25 to 29, with values in excess of 30 considered obese (Flegal 1999:S509).

According to Table 1.2.2.2, research on gender differences in the proportions of persons who are overweight has provided mixed findings, although most studies indicate that a greater proportion of females than males are overweight, especially after adolescence.

Table 1.2.2.2. Overweight.

Nature of Any Difference	Prepubertal			Postpubertal		Multiple Age Categories
	Toddler	Early Childhood	Childhood	Adolescent	Adult	
More in males			LATIN AMERICA <i>Chile</i> : Olivares et al. 2004:1281 NORTH AMERICA <i>United States</i> : Troiano et al. 1995; TJ Cole et al. 2000	ASIA <i>Japan</i> : Kouida et al. 2004:80 (young, BMI > 25)	EUROPE <i>Belgium</i> : Moens et al. 1999 NORTH AMERICA <i>Canada</i> : Millar & Stephens 1993; <i>United States</i> : Metropolitan Life Insurance Company 1960 (elderly); Flegal et al. 1998* (1960s); Flegal et al. 1998* (1980s); Kabeer et al. 2001:129; Paeratakul et al. 2002:1206; Cleary et al. 2004:51* (middle aged) OCEANIA <i>New Zealand</i> : Simmons et al. 1996	EUROPE <i>Britain</i> : Hill & Roberts 1998:207 NORTH AMERICA <i>Canada</i> : Choiniere et al. 2000:S15; <i>United States</i> : CE Ross & Mirowsky 1983; Flegal et al. 1998; Klatsky & Armstrong 1991 (Asians); Lauderdale & Rathoug 2000
No signif. difference	LATIN AMERICA <i>Brazil</i> : Monteiro et al. 1995*	LATIN AMERICA <i>Brazil</i> : Monteiro et al. 1995*		NORTH AMERICA <i>United States</i> : Giammattei et al. 2003	EUROPE <i>Belgium</i> : Kornitzer & Bora 1989 NORTH AMERICA <i>United States</i> : Wingard et al. 1983 (Whites); DM Zuckerman et al. 1986 (college, using official standards); JK Mills & Cunningham 1988	
More in females			EUROPE <i>Britain</i> : Chinn & Rone 2001; <i>Germany</i> : Kromeyer-Hauschild et al. 1999; S Danielzik et al. 2004 (5-7 year olds); <i>Scotland</i> : Troiano & Flegal 1998; <i>Sweden</i> : IM Berg et al. 2001; S Petersen et al. 2003:850 NORTH AMERICA <i>United States</i> : Flegal et al. 2001; Kalies et al. 2002:1214 OCEANIA <i>Australia</i> : ML Booth et al. 1999*; Kirchengast & Steiner 2001	OCEANIA <i>Australia</i> : ML Booth et al. 1999*; Magarey et al. 2001	ASIA <i>China</i> : Popkin et al. 1995; <i>Russia</i> : Jahns et al. 2003 EUROPE <i>Belgium</i> : Moens et al. 1999; <i>Netherlands</i> : Berns 1995; <i>Spain</i> : Gutierrez-Fisac et al. 1995; <i>Sweden</i> : Kuskowska-Wolk & Bergstrom 1993a/1993b NORTH AMERICA <i>Canada</i> : Millar & Stephens 1993; <i>United States</i> : Metropolitan Life Insurance Company 1960 (elderly); US Dept of HEW 1965; US Dept of HEW 1975; Cleary et al. 2004:51* (young adult and elderly) OCEANIA <i>New Zealand</i> : Simmons et al. 1996	LATIN AMERICA <i>Brazil</i> : Y Wang et al. 2002:973 NORTH AMERICA <i>Canada</i> : Choiniere et al. 2000:S15; <i>United States</i> : CE Ross & Mirowsky 1983; Flegal et al. 1998; Klatsky & Armstrong 1991 (Orientals); Lauderdale & Rathouz 2000

1.2.2.3. Obesity

Obesity is usually defined in medical-scientific terms as having a body mass index (BMI) that is 30 or greater. According to most studies (Table 1.2.2.3), obesity is more common in females than in males, although several exceptions have been reported.

Table 1.2.2.3. Obesity.

Nature of Any Difference	Prepubertal		Postpubertal		Multiple Age Categories
	Childhood	Adolescent	Adolescent	Adult	
More in males	LATIN AMERICA <i>Chile</i> : Kain et al. 2002; Olivares et al. 2004:1281			EUROPE <i>Hungary</i> : Antal et al. 2003	EUROPE <i>Belgium</i> : Moens et al. 1999
No signif differ		NORTH AMERICA <i>United States</i> : Troiano & Flegal 1998		EUROPE <i>Belgium</i> : Kornitzer & Bara 1989; <i>Finland</i> : Pietinen et al. 1996 OCEANIA <i>Australia</i> : Bennett & Magnus 1994; <i>Mauritius</i> : Hodge 1996	EUROPE <i>Britain</i> : Hill & Roberts 1998:207
More in females	EUROPE <i>Britain</i> : Chinn & Rone 2001; <i>Germany</i> : Kromeyer-Hauschild et al. 1999 NORTH AMERICA <i>United States</i> : Kalies et al. 2002:1214	EUROPE <i>Germany</i> : Danielzik et al. 2004 (5-7 year olds) OCEANIA <i>Australia</i> : Magarey et al. 2001	ASIA <i>Russia</i> : Jahns et al. 2003 EUROPE <i>Italy</i> : Perissinotto et al. 2002 (elderly); <i>Poland</i> : Rogucka & Bielicki 1999:420 MIDDLE EAST <i>Israel</i> : Gofin et al. 1996 (elderly) NORTH AMERICA <i>United States</i> : S Abraham et al. 1975; Schoenborn et al. 1981; Flegal et al. 1988* (elderly); Paeratakul et al. 2002:1206; Murtagh & Hubert 2004:1409 (elderly)		LATIN AMERICA <i>Brazil</i> : Sichieri et al. 1994 NORTH AMERICA <i>United States</i> : National Center for Health Statistics 1981; C Power et al. 1997:1501; Flegal et al. 1998 OCEANIA <i>Western Samoa</i> : Hodge et al. 1994:421

1.2.2.4. Association Between Social Status and Being Overweight or Obese

Many studies have found that the prevalence of being overweight or obese is greater among persons of low social status than among those of high status, at least in developed countries (e.g., Register & Williams 1990; Gortmaker et al. 1993; Rosmond & Bjorntorp 1999; Paeratakul et al. 2002). As summarized in Table 1.2.2.4, a few studies have sought to determine if this status-overweight association is more pronounced in one sex than in the other. In all of these studies, the relationship was found to be stronger for females than for males.

Table 1.2.2.4. Association between social status and being overweight or obese.

Nature of Any Difference	Postpubertal			
	Adult			
More among males				
No signif. difference				
More among females				EUROPE <i>Britain</i> : Power et al. 1997:1502; <i>Finland</i> : Sarlio-Lahteenkorva & Lahela 1999; <i>France</i> : Maillard et al. 1999 NORTH AMERICA <i>United States</i> : RW Jeffrey et al. 1989; Leigh et al. 1992

1.2.2.5. Underweight

Although somewhat difficult to define, underweight can be determined by body mass index (BMI) and the body weight/desired weight (W/DW) ratio. Studies have not come to consistent conclusions regarding which gender is most likely to be underweight, although the available evidence seems to suggest that the proportion of males who are underweight becomes greater with age (Table 1.2.2.5).

Table 1.2.2.5. Underweight.

Nature of Any Difference	Sub-Adolescent			Postpubertal
	Infant	Toddler	Early Childhood	Adult
Males more				ASIA <i>China</i> : Y Wang et al. 2002:973* LATIN AMERICA <i>Brazil</i> : Y Wang et al. 2002:973*
No signif. difference				NORTH AMERICA <i>United States</i> : Wingard et al. 1983:167 (White)
Females more	MIDDLE EAST <i>Egypt</i> : Ahmed et al. 1981	MIDDLE EAST <i>Egypt</i> : Tekce 1990; <i>Jordan</i> : Doan & Bisharat 1990	MIDDLE EAST <i>Egypt</i> : Tekce & Shorter 1984	NORTH AMERICA <i>United States</i> : Paeratakul et al. 2002:1207

1.2.2.6. Percent Body Fat and Skinfold Thickness

Overall body fat is determined by the proportion of one's body that is comprised of fat (as opposed to muscle, nerves, and other nonfat tissue), much of which is found under the skin. Numerous studies have investigated sex differences in overall body fat and skinfold thickness. As shown in Table 1.2.2.6a, most studies of prepubertal humans have concluded that females have a greater proportion of body fat than do males.

Split-Table 1.2.2.6a. Percent body fat and skinfold thickness among prepubertals.

Nature of Any Difference	Prepubertal	
	Infant	Childhood
Males have more		
No signif. difference		NORTH AMERICA <i>United States</i> : EL Reynolds 1950*; GB Forbes & Hursh 1963:261*
Females have more	EUROPE <i>France</i> : Guihard-Costa et al. 1997 NORTH AMERICA <i>United States</i> : Gampel 1965; Oakley & Parsons 1977; G Farmer 1985 (skinfold thickness)	ASIA <i>China</i> : Li et al. 2005* EUROPE <i>Germany</i> : Mast et al. 1998 NORTH AMERICA <i>United States</i> : Gabbard & Tandy 1988:155 OCEANIA <i>New Zealand</i> : EC Rush et al. 2003:3

In the case of postpubertal humans, the findings are unanimous in concluding that females have a greater percent of body fat and/or skinfold thickness (Split-Table 1.2.2.6b).

Split-Table 1.2.2.6b. Percent body fat and skinfold thickness among postpubertals.

Nature of Any Difference	Postpubertal				Multiple Age Categories
	Adolescent		Adult		
Males have more			RODENT Rat: Cortright et al. 1997		
No signif. difference					
Females have more	ASIA China: Li et al. 2005* (early adolescence)	NORTH AMERICA United States: EL Reynolds 1950*; Reba et al. 1968; Malina 1975; G Forbes 1987; Dai et al. 2002	EUROPE Denmark: Roepstorff et al. 2002:E43b (young); Sweden: Hellstrom et al. 2000:459	LATIN AMERICA Bahamas: Mazess 1967 (Blacks)	EUROPE Netherlands: Parizkova 1977
	OCEANIA Australia: Magarey et al. 1999:140		NORTH AMERICA Canada: Marliss et al. 2000:458; United States: CM Young et al. 1963; PE Watson et al. 1980 (young); SM Bailey & Katch 1981; AW Marshall et al. 1983; Goist & Sutker 1985; Considine et al. 1996; Sanborn & Jankowski 1994 (young); Haffner et al. 1996 (Mexican-American); Kwo et al. 1998:1554 (young); Pritzlaff et al. 1999; AS Jackson et al. 2002:791	NORTH AMERICA United States: GB Forbes & Hursh 1963:261; Pierson et al. 1974; Seltzer & Mayer 1965	INTERNATIONAL Multiple Countries: International Committee on Radiological Protection 1975
			OCEANIA Australia: A Wright et al. 2002 (young)		

1.2.2.7. Body Fat Distribution in the Upper Body

Research indicates that male concentration of body fat is greater in the chest and shoulders than is true for females (Table 1.2.2.7).

Table 1.2.2.7. Body fat distribution in the upper body.

Nature of Any Difference	Multiple Age Categories			
	Males have more			
No signif. difference				NORTH AMERICA United States: Vague 1956; Kissebah et al. 1982; Krotkiewski et al. 1983; Bjorntorp 1984; Vague et al. 1988; Comuzzie et al. 1995 (Mexican Americans)
Females have more				

1.2.2.8. Body Fat Distribution in the Lower Body

At least among adolescents and adults, females have been shown to have more concentrated body fat in the hips and thighs than is true for males (Table 1.2.2.8).

Table 1.2.2.8. Body fat distribution in the lower body.

Nature of Any Difference	Multiple Age Categories			
	Males have more			
No signif. difference				
Females have more				NORTH AMERICA United States: Vague 1956; Kissebah et al. 1982; Bjorntorp 1984; Vague et al. 1988

1.2.2.9. Subcutaneous Fat/Amount of Body Fat

Subcutaneous fat is that which is stored in the fatty tissue under the skin (subcutaneous tissue) as opposed to that in the abdominal cavity (intra-abdominal tissue) and within the muscles – particularly in older adults. Table 1.2.2.9 suggests that at least for most age categories, females have more subcutaneous fat than do males.

Table 1.2.2.9. Subcutaneous fat/amount of body fat.

Nature of Any Difference	Prepubertal			Postpubertal	
	Infant	Toddler	Childhood	Adolescent	Adult
More in males					
No signif. difference			EUROPE Britain: WH Hammond 1955:206*		
More in females	EUROPE France: Guihard-Costa et al. 2002		EUROPE Britain: WH Hammond 1955:206*	EUROPE Britain: WH Hammond 1955:206*	RODENT Mouse: Wiedmer et al. 2004:2861
	NORTH AMERICA United States: Stolz & Stolz 1951			NORTH AMERICA United States: DD Marino & King 1980	

1.2.2.10. Waist-to-Hip Ratio

The waist-to-hip ratio is calculated by dividing the waist circumference by the hip circumference. Nearly all studies have concluded that the waist-to-hip ratio is greater for males than for females (Table 1.2.2.10).

Table 1.2.2.10. Waist-to-hip ratio.

Nature of Any Difference	Childhood			Postpubertal		Multiple Age Categories
				Adult		
Males higher		EUROPE <i>Germany:</i> Bottner et al. 2004:4054* (ages 8 to 11)	EUROPE <i>Germany:</i> Bottner et al. 2004:4054* (ages 12 to 18)	ASIA <i>Taiwan:</i> K.-C. Lin et al. 2004 (30 years and older) EUROPE <i>Germany:</i> Bottner et al. 2004:4054*(ages 8 to 18); <i>Italy:</i> Perissinotto et al. 2002 (elderly); <i>Netherlands:</i> Stolk et al. 1996:314; <i>Sweden:</i> Hellstrom et al. 2000:459; <i>Multiple European Countries:</i> Langerberg et al. 2003 (53 year olds) NORTH AMERICA <i>Canada:</i> Ledoux et al. 1997; <i>United States:</i> Cnop et al. 2003:461; Cleary et al. 2004:50		NORTH AMERICA <i>United States:</i> EpeI et al. 1999:12; Pascot et al. 2002:401
No signif. difference						
Females higher				NORTH AMERICA <i>United States:</i> Comuzzie et al. 1993:730(Mexican Americans)		

1.2.2.11. Body Proportions in the Pelvic Region

According to Table 1.2.2.11, there may be various subtle sex differences in the pelvic structures of male and female rats.

Table 1.2.2.11. Body proportions in the pelvic region.

Nature of Any Difference	Childhood			Postpubertal	
				Adult	
Greater in males				RODENT <i>Rat:</i> P Bernstein & Crelin 1967* (pelvic width, crest tuberosity distance, curvature of the ischial ramos, length of the ischium & the symphysis, vertebral level of the pubic symphis; width of the obturator foramen)	
No signif. difference					
Greater in females				RODENT <i>Rat:</i> P Bernstein & Crelin 1967* (subpubic angle)	

1.2.2.12. Relative Size of the Extremities

One study of monkeys found that the size of all basic extremities were greater in males than in females even after adjusting for sex differences in overall size (Table 1.2.2.12).

Table 1.2.2.12. Relative size of the extremities.

Nature of Any Difference	Childhood			Postpubertal	
				Adult	
Greater in males				PRIMATE (EXCEPT APE) <i>Rhesus Monkey:</i> JA Vilensky 1979 (trunk, forearm, hand, leg, foot, and tail)	
No signif. difference					
Greater in females					

1.2.3. Weight Gain and Weight Loss

Sex differences in weight gain have been investigated for both humans and other animals under a variety of specified conditions.

1.2.3.1. Weight Gain With Age

In adulthood, nearly all humans gradually increase in weight with age. Table 1.2.3.1 indicates that the rate of gain tends to be more for females than for males.

Table 1.2.3.1. Weight gain with age.

Nature of Any Difference	Childhood			Postpubertal	
				Adult	
Males gain more					
No signif. difference					
Females gain more				EUROPE <i>Denmark:</i> Heitmann 1991; <i>Finland:</i> Lahti-Koski et al. 2001 NORTH AMERICA <i>United States:</i> G Forbes & Reina 1970; Parizkova 1973; Bray 1976; Enzi et al. 1986	

1.2.3.2. Weight Gain Associated With Depression

Persons who are depressed often experience significant weight gain. Most of the evidence pertaining to this phenomenon indicates that this type of weight gain is more characteristic of females than of males, although two studies found no significant sex difference (Table 1.2.3.2).

Table 1.2.3.2. Weight gain associated with depression.

Nature of Any Difference					Postpubertal	
					Adolescent	Adult
Males gain more						
No signif. difference					NORTH AMERICA <i>United States</i> : MA Young et al. 1990; Benazzi 1999	
Females gain more					EUROPE <i>Italy</i> : Perugi et al. 1990 NORTH AMERICA <i>United States</i> : Kornstein et al. 1995; Kornstein et al. 2000; Khan et al. 2002 (among opposite sex twins)	

1.2.3.3. Weight Gain Following Amygdaloidal Lesion

Several studies of rodents have found that a physically damaged amygdala results in greater weight gains among females than among males (Table 1.2.3.3).

Table 1.2.3.3. Weight gain following amygdaloidal lesion.

Nature of Any Difference					Postpubertal	
					Adolescent	Adult
Males gain more						
No signif. difference						
Females gain more					RODENT <i>Rat</i> : Pi et al. 1964	RODENT <i>Mouse</i> : MK Sanders et al. 1973; <i>Rat</i> : Bernardis et al. 1963; Singh & Meyer 1968; V Cox et al. 1969; D Singh 1970; Grossman & Hennessy 1976; BM King & Frohman 1986; BM King et al. 1999

1.2.3.4. Weight Gain Following Intermittent Starvation

One study subjected mice to periodic starvation. They found that when allowed to free feed afterward, males gained more weight than did females (Table 1.2.3.4).

Table 1.2.3.4. Weight gain following intermittent starvation.

Nature of Any Difference					Postpubertal	
					Adolescent	Adult
Males gain more						
No signif. difference					RODENT <i>Mouse</i> : T Robertson et al. 1934	
Females gain more						

1.2.3.5. Weight Gain Following Ventromedial Hypothalamic (VMH) Lesion

Most experiments in which lesions were made in the ventromedial hypothalamus of rodents have found that females gain more weight than do males (Table 1.2.3.5).

Table 1.2.3.5. Weight gain following ventromedial hypothalamic (VMH) lesion.

Nature of Any Difference					Postpubertal	
					Adolescent	Adult
Males gain more						
No signif. difference					RODENT <i>Rat</i> : Rehovnsky & Wampler 1972 (young)	
Females gain more					RODENT <i>Rat</i> : Pi et al. 1964	RODENT <i>Mouse</i> : MK Sanders et al. 1973 (young); <i>Rat</i> : D Singh & Meyer 1968 (young); VJ Cox et al. 1969 (young); Grossman & Hennessy 1976 (young); BM King & Frohman 1986 (young)

1.2.3.6. Weight Gain (BMI Increase) Following Induced Systolic Blood Pressure

One study concluded that females experience greater weight gain following systolic blood pressure inductions when compared to males (Table 1.2.3.6).

Table 1.2.4.1. Size of muscle/muscle mass.

Nature of Any Difference	Prepubertal			Postpubertal			Multiple Age Categories
	Infant			Adult			
Males greater	NORTH AMERICA <i>United States:</i> Garn 1957; Garn 1958			ASIA <i>Japan:</i> Kanehisa et al. 2003 (trained athletes) EUROPE <i>Britain:</i> AE Miller et al. 1993 (thicker muscle fibers); <i>Sweden:</i> Komi & Karlsson 1978 (young); Liljedahl et al. 1996 NORTH AMERICA <i>Canada:</i> Simoneau et al. 1985; <i>United States:</i> A Keys & Brozek 1953 (higher proportion of muscle mass); Andersen 1963 (higher proportion of muscle mass); Malina 1978 (higher proportion of muscle mass); HJ Green et al. 1984; Sale et al. 1987 (thicker muscle fibers); Esbjornsson et al. 1993; Sanborn & Jankowski. 1994 (young); Chow et al. 2000* (thicker leg muscle fibers; Nicolay & Walker 2005:607 (larger forearm circumference) AMPHIBIAN <i>Green Anole Lizard:</i> J Wade 1998 (ceratohyoid muscle); <i>Toad:</i> MT Lima-Landman & Lapa 1998 (sternodales forelimb muscle when equaled for body size) CANINE <i>Hyena:</i> NG Forger et al. 1996 (bulbocavernosus muscle) RODENT <i>Mouse:</i> Glenmark et al. 2004			EUROPE <i>Britain:</i> AE Miller et al. 1993
No signif. diff.							
Females greater				NORTH AMERICA <i>United States:</i> Chow et al. 2000* (leg muscle fiber length)			

1.2.4.2. Muscular Flexibility

In a relatively few studies of muscular flexibility, females have been shown to surpass males (Table 1.2.4.2).

Table 1.2.4.2. Muscular flexibility.

Nature of Any Difference				Postpubertal			
				Adolescent			
Males greater							
No signif. diff.							
Females greater				EUROPE <i>Poland:</i> Thurzova 1998 (hamstring) NORTH AMERICA <i>United States:</i> Bach et al. 1985 (hamstring); S Wang et al. 1993 (hamstring); Nyland et al. 2004 (hamstring)			

1.2.4.3. Muscle Strength

Given that males have greater muscle mass than females (see above), muscular strength is greater for males. Table 1.2.4.3 confirms this expectation.

Table 1.2.4.3. Muscle strength.

Nature of Any Difference	Pre-pubertal			Postpubertal			Multiple Age Categories
	Infant	Childhood	Adolescent	Adult			
Males greater	NORTH AMERICA <i>United States:</i> RQ Bell & Darling 1965 (lifting head higher when on stomach)	ASIA <i>Japan:</i> Kanehisa et al. 1994 (leg muscle)	NORTH AMERICA <i>United States:</i> Jones 1947 OCEANIA <i>Australia:</i> R Fletcher & Hattie 2005:663 (self-rated, weight lifting)	EUROPE <i>Britain:</i> Maughan et al. 1983 (stronger muscles); AE Miller et al. 1993; SK Phillips et al. 1993 (elderly); <i>France:</i> Ochala et al. 2004 (elderly, muscular torque); <i>Sweden:</i> Komi & Karlsson 1978; Liljedahl et al. 1996 MIDDLE EAST <i>Turkey:</i> Asci 2002:368 (young, self-rated) NORTH AMERICA <i>Canada:</i> Simoneau et al. 1985; JA Hall & Kimura 1995 (hand strength); <i>United States:</i> Aniansson et al. 1981 (elderly); HJ Green et al. 1984; Homant & Kennedy 1985 (upper body, police officers); Petersen et al. 1989 (grip strength); Doherty et al. 1993 (elderly); Esbjornsson et al. 1993; Hurlley 1995 (elderly, grip); Bohannon 1997 (grip); Lindle et al. 1997; Sonstroem 1998 (young, self-rated strength); Oman et al. 1999 (lower body strength, elderly); Frontera et al. 2000 (elderly); Nevill & Holder 2000 (grip strength); Seeman 2001; Nicolay & Walker 2005 (grip strength) RODENT <i>Mouse:</i> Glenmark et al. 2004			MIDDLE EAST <i>India:</i> Padmavathi et al. 1999; Vaz et al. 2002 (grip) NORTH AMERICA <i>United States:</i> FW Smedley 1902 (grip)
No signif. difference							
Females greater							

1.2.4.4. Muscular Body Build (Mesomorphy/Broad Shoulders-Narrow Hips)

Numerous studies have documented that among humans males have a more muscular (mesomorphic) body build than do females, at least following the onset of puberty (Table 1.2.4.4). The muscular development of males is especially pronounced in the shoulder portions of the body. Similar evidence is available for nonhuman species as well.

Table 1.2.4.4. Muscular body build (mesomorphy/broad shoulders-narrow hips).

Nature of Any Difference	Prepubertal		Postpubertal		Multiple Age Categories
	Childhood		Adolescent		
Males more	NORTH AMERICA <i>United States</i> : M Phillips et al. 1955; Kirchner & Glines 1957; Branta et al. 1984*; M Jones et al. 1986		MIDDLE EAST <i>India</i> : Hauspie et al. 1985* EUROPE <i>Britain</i> : Hauspie et al. 1985*; <i>Germany</i> : Zeller 1939; Schmidt-Voight 1942 NORTH AMERICA <i>United States</i> : N Bayley 1943; K Simmons & Greulich 1943; Muhsam 1947; Branta et al. 1984*		AMPHIBIAN <i>Frog</i> : Sassoon & Kelley 1986; Sassoon et al. 1987 RODENT <i>Rat</i> : Breedlove & Arnold 1983a; Breedlove & Arnold 1983b
No signif. difference	NORTH AMERICA <i>United States</i> : K Simmons & Greulich 1943				
Females more					

1.2.4.5. Muscle Sympathetic Nerve Activity

Males have been found to exhibit greater muscle sympathetic nerve activity than females (Table 1.2.4.5).

Table 1.2.4.5. Muscle sympathetic nerve activity.

Nature of Any Difference	Prepubertal		Postpubertal	
	Childhood		Adult	
Male nerves more sympathetic			NORTH AMERICA <i>United States</i> : Ng et al. 1993 (at rest)*; PP Jones et al. 1996a (young); PP Jones et al. 1996b (young)	
No significant difference				
Female nerves more sympathetic				

1.2.4.6. Muscular Endurance

Two studies have found the muscular endurance of males surpassing that of females (Table 1.2.4.6).

Table 1.2.4.6. Muscular endurance.

Nature of Any Difference	Prepubertal		Postpubertal	
	Childhood		Adult	
Males more			EUROPE <i>Britain</i> : AE Miller et al. 1993 (isometric contractions at low to moderate intensity); Maughan et al. 1986 (isometric contractions at low to moderate intensity)	
No significant difference				
Females more				

1.2.4.7. Muscle Fatigue Resistance

In several studies, females were found to exhibit greater resistance to muscle fatigue than males (Table 1.2.4.7).

Table 1.2.4.7. Muscle fatigue resistance.

Nature of Any Difference	Prepubertal		Postpubertal	
	Childhood		Adult	
Male more				
No significant difference				
Females more			EUROPE <i>Finland</i> : Hakkinen 1993; <i>Sweden</i> : Linnamo et al. 1998 NORTH AMERICA <i>United States</i> : Fulco et al. 1999 RODENT <i>Mouse</i> : Glenmark et al. 2004	

1.2.4.8. Size of Bulbocavernosus Muscles

The spinal nucleus of the bulbocavernosus pertains to muscles in the groin area. Table 1.2.4.8 shows that at least among rats, this muscle tissue is considerably larger in males than in females.

Table 1.2.4.8. Size of bulbocavernosus muscles.

Nature of Any Difference	Postpubertal			
	Adult			
Males larger				RODENT Rat: MC Crark et al. 1993 (spinal nucleus larger); Hays et al. 1993 (spinal nucleus larger); Mills & Sengelaub 1993 (spinal nucleus larger)
No significant difference				
Females larger				

1.2.5. Other Morphological Traits

Morphological traits are ones having to do with one’s body structure. A couple of specific morphologic traits (apart from those pertaining to body size, which has already been considered) have been investigated with respect to sex differences and are reviewed below.

1.2.5.1. Dermal Ridge Count

The number of ridges in one’s finger prints is referred to as the dermal ridge count. One study found no significant gender difference in this count, while a more recent study found males with a count that surpassed that of females (Table 1.2.5.1).

Table 1.2.5.1. Dermal ridge count.

Nature of Any Difference	Postpubertal			
	Adult			
Males greater				NORTH AMERICA Canada: Kimura & Carson 1993 (young)
No signif. difference				NORTH AMERICA United States: Holt 1968 (young)
Females greater				

1.2.5.2. Galvanic Skin Response (GSR, Skin Conductivity)

One physical symptom of nervousness is the degree to which individuals sweat. An instrument known as the Galvanic Skin Response (GSR) measures the degree of sweating in the palms. The device works by using the hand to complete an electrical circuit when two fingers are placed on two unconnected electrodes. The electrical current is so small that it is not detectable to subjects. The more one sweats, the more rapidly the electrical current flows.

A few studies have sought to determine if a gender difference exists in the GSR. As shown in Table 1.2.5.2, most studies indicate that females register a higher GSR than males, although a few studies indicate that the answer may depend on detailed circumstances under which tests were conducted.

Table 1.2.5.2. Galvanic skin response (GSR, skin conductivity).

Nature of Any Difference	Prepubertal			Postpubertal	Multiple Age Categories
	Infant	Early Childhood	Childhood	Adult	
Males higher			NORTH AMERICA United States: Fabes et al. 1994 (when watching a disturbing film)	EUROPE Britain: Evans & Steptoe 2003:765* (normal resting nonstressed)	
No signif. difference					
Females higher	NORTH AMERICA United States: GM Weller & Bell 1965 (neonate)	NORTH AMERICA United States: Zahn-Waxler et al. 1995 (when distressed)	NORTH AMERICA United States: Riggness 1962; Eisenberg et al. 1991b (in response to sympathy-inducing stimuli)	EUROPE Britain: Evans & Steptoe 2003:765* (when stressed); Norway: Johnsen et al. 1995 (in response to emotional facial expressions) NORTH AMERICA United States: MM Bradley et al. 2001 (in response to aversive visual stimulation)	NORTH AMERICA Canada: VJ Knott 1984

1.2.5.3. Skin Conductivity Baseline Recovery

According to the one study located, skin conductivity of males was slower to return to baseline after being elevated due to stress than was the case for females (Table 1.2.5.3).

Table 1.2.5.3. Skin conductivity baseline recovery.

Nature of Any Difference	Prepubertal		
		Childhood	
Males longer			NORTH AMERICA <i>United States</i> : Fabes 1994
No signif. difference			
Females longer			

1.2.5.4. Finger Length/Hand Size

Given that adult males are larger than adult females, it is to be expected that the fingers of males would be larger than those of females, and is thus indicated by the one available study (Table 1.2.5.4).

Table 1.2.5.4. Finger length/hand size.

Nature of Any Difference	Postpubertal		
		Adult	
Males larger			NORTH AMERICA <i>Canada</i> : JA Hall & Kimura 1995 (finger length); <i>United States</i> : Nicolay & Walker 2005:607 (hand size)
No signif. difference			
Females larger			

1.2.5.5. 2D:4D Ratio (Length of the 2nd Digit Relative to the 4th Digit)

At least among humans, exposing the fetus to high (male-typical) levels of testosterone during critical stages in development appears to lengthen the second digit relative to the fourth digit (especially on the left hand). Consistent with this evidence on the effects of testosterone, Table 1.2.5.5 indicates that males on average have a longer second digit relative to their fourth digit when compared to females. It is notable that the one study to report the opposite pattern was confined to rodents.

Table 1.2.5.5. 2D:4D Ratio (length of the 2nd digit relative to the 4th digit).

Nature of Any Difference	Prepubertals		Postpubertal		Multiple Age Categories
		Childhood		Adult	
Males have longer 2 nd D than 4 th D		EUROPE <i>Britain</i> : Buck et al. 2003 MIDDLE EAST <i>Turkey</i> : Okten et al. 2002		ASIA <i>Russia</i> : Wolotzkoi 1924; Huizinga 1949 EUROPE <i>Britain</i> : JT Manning et al. 1998; JT Manning & Bundred 2000; Sluming & Manning 2000; <i>Germany</i> : Ecker 1875; Weissenberg 1895 NORTH AMERICA <i>Canada</i> : M Peters et al. 2002 (college); <i>United States</i> : F Baker 1888; George 1930; VR Phelps 1952; Lippa 2003	INTERNATIONAL <i>Multiple Countries</i> : JT Manning et al. 2000
No signif. difference					
Females have longer 2 nd D than 4 th D					RODENT <i>Rat</i> : WM Brown et al. 2001

1.2.5.6. Relationship Between 2D:4D and Facial Asymmetry

A study of sex differences in the relationship between the 2D:4D ratio and the degree of facial asymmetry indicated that it was positive in the case of females and negative in the case of males (Table 1.2.5.6).

Table 1.2.5.6. Relationship between 2D:4D and facial asymmetry.

Nature of Any Difference	Postpubertal		
		Adult	
Males more			EUROPE <i>Austria</i> : Fink et al. 2004* (negative related to facial asymmetry in males) (LE)
No signif. difference			
Females more			EUROPE <i>Austria</i> : Fink et al. 2004* (positive related to facial asymmetry in males) (LE)

1.3

INTERNAL ORGANS AND BODILY STRUCTURES (EXCEPT THE BRAIN)

In this section, a number of variables are discussed that have to do with structures such as the teeth, bones, and skin. Also covered are factors that have to do with glands and other bodily organs.

1.3.1. Teeth

Variables pertaining to teeth structures as well as to the age at which teeth erupt and decay are discussed below.

1.3.1.1. Teeth Calcification

The only study located concerning teeth calcification concluded that it is more pronounced (with age control) and occurs earlier in females than in males (Table 1.3.1.1).

Table 1.3.1.1. Teeth calcification.

Nature of Any Difference	Prepubertal		Childhood	
	Males more			
No signif. difference				
Females more				NORTH AMERICA <i>United States</i> : Demirjian 1978

1.3.1.2. Appearance of Permanent Dentition, Age at

In humans, the permanent (adult) teeth nearly always appear prior to the onset of puberty. As to whether males or females received their permanent teeth earlier, the evidence is conflicting. In Table 1.3.1.2, two studies suggest that this occurs sooner among females and one study indicated the opposite.

Table 1.3.1.2. Appearance of permanent dentition, age at.

Nature of Any Difference	Citations
Earlier for males	NORTH AMERICA <i>United States</i> : White House Conference 1932
No signif. difference	
Earlier for females	NORTH AMERICA <i>United States</i> : P Cattell 1928; H Klein et al. 1937

1.3.1.3. Canine Tooth Length

The length of the canine tooth is measured with a ruler (usually calibrated in meters). Table 1.3.1.3 suggests that in humans, in their distant extinct ancestors (the Australopithecus), and in other primate species, males have significantly longer canine teeth than do females.

Table 1.3.1.3. Canine tooth length.

Nature of Any Difference	Postpubertal		Multiple Age Categories
	Adult		
Males larger		PRIMATE (EXCEPT APE) <i>Brown Capuchins</i> : Masterton 2003; <i>Colobus Monkey</i> : Hayes et al. 1995 (black & white); <i>Golden Monkey</i> : Pan & Oxnard 2001; <i>Snub-Nosed Monkey</i> : Jablonoski & Ruliang 1995 (four species); <i>Vervet Monkeys</i> : NM Durham 1969	OCEANIA <i>Australia</i> : Gingerich 1981 HOMINID <i>Australopithecus</i> : Fleagle et al. 1980; Fedigam 1982 MULTIPLE SPECIES <i>Several Primate (except ape) Species</i> : Leutenegger 1982* (39/42 species); RF Kay et al. 1988
No signif. difference		PRIMATE (EXCEPT APE) <i>Ring-Tailed Lemur</i> : Sauthes et al. 2001; <i>Sifaka</i> : Lawler et al. 2005 (wild caught); <i>Talapoin</i> : Segre 1970	MULTIPLE SPECIES <i>Several Primate (except ape) Species</i> : Leutenegger 1982* (3/42 species)
Females larger			PRIMATE (EXCEPT APE) <i>Lemur</i> : Kappeler 1996

1.3.1.4. Diameter of Dental Crown

As shown in Table 1.3.1.4, the dental crown of males is larger than that of females. One research team asserted that the gender difference is between 5 to 10% (Yamada & Sakai 1992).

Table 1.3.1.4. Diameter of dental crown.

Nature of Any Difference	Multiple Age Categories	
Larger for males		EUROPE <i>Finland</i> : Alvesalo 1971 NORTH AMERICA <i>United States</i> : Garn et al. 1967a; Garn et al. 1967b OCEANIA <i>Cook Island</i> : Yamada & Sakai 1992
No signif. difference		
Larger for females		

1.3.2. Bones and Joints

Research on gender differences in the bones considers such factors as density and the rates at which they grow.

1.3.2.1a. Bone Density/Bone Mass

Among humans, while the bone density of males and females appear to be equivalent among prepubertals, within a few years following puberty, nearly all studies have found males exhibiting greater bone density than females (Split-Table 1.3.2.1a).

Split-Table 1.3.2.1a. Bone density/bone mass.

Nature of Any Difference	Prepubertal		Postpubertal		Multiple Age Categories
	Childhood	Adolescent		Adult	
		Early	Late		
Males greater			NORTH AMERICA <i>United States</i> : Bachrach et al. 1999; Bonjour et al. 1991; Theintz et al. 1992; Gunnes 1994 (bone mineral content); K Rubin et al. 1993* (bone mineral content) OCEANIA <i>Australia</i> : Magarey et al. 1999:141 (higher bone mineral content)	ASIA <i>China</i> : Yan et al. 2002* (elderly); Lei et al. 2004:73 (elderly) EUROPE <i>Denmark</i> : Mosekilde & Mosekilde 1990; <i>Poland</i> : Rogucka et al. 2000* (young); Rogucka et al. 2000*; <i>Spain</i> : Diaz Curiel et al. 1997 NORTH AMERICA <i>United States</i> : Jansson et al. 1983; Aaron et al. 1987; Greenspan et al. 1994 (bone mineral density, elderly); RA Faulkner et al. 1995 (elderly); Gallagher et al. 1997; Greendale et al. 1997 (elderly); YM Henry & Eastell 2000 (young); Janssen et al. 2000; Orwoll 2000; Looker et al. 2001; Orwoll et al. 2001*; Seeman 2001; Naganathan et al. 2002; EL Duncan et al. 2003; Kammerer et al. 2003 (Mexican Americans); Karasik et al. 2003:311; Stini 2003:41 (middle age & elderly); Taafee et al. 2003 (elderly); Masi et al. 2004 (elderly); Nicolay & Walker 2005 (wrist circumference) OCEANIA <i>Australia</i> : Duan et al. 2001:2270 (vertebra)	ASIA <i>Japan</i> : Sakaue 1998 EUROPE <i>Italy</i> : Foresta et al. 1983a; Foresta et al. 1983b NORTH AMERICA <i>United States</i> : Riggs et al. 1981 (bone mineral density)
No signif. difference	NORTH AMERICA <i>United States</i> : K Rubin et al. 1993* (bone mineral content)	NORTH AMERICA <i>United States</i> : Gilsanz et al. 1988; K Rubin et al. 1993* (bone mineral content)		ASIA <i>China</i> : Yan et al. 2002* (middle age)	
Females greater					

1.3.2.1b. Bone Density/Bone Mass for Nonhumans

According to Split-Table 1.3.2.1b, the evidence is somewhat inconsistent among rats regarding any sex difference in bone density or mass. Among the few studies of primates, however, findings all suggest that males surpass females in bone density and mass.

Split-Table 1.3.2.1b. Bone density/bone mass for nonhumans.

Nature of Any Difference			Postpubertal		Multiple Age Categories
			Adolescent		
			Late		
Males greater			RODENT <i>Rat</i> : XZ Zhang et al. 1999; Schoenau et al. 2001	PRIMATE (EXCEPT APE) <i>Baboon</i> : Havill et al. 2003; <i>Rhesus Macaque</i> : Colman et al. 1999 RODENT <i>Mouse</i> : Orwoll et al. 2001*; <i>Rat</i> : Vanderschueren et al. 1994* (femoral bone mass and area); BT Kim et al. 2003	PRIMATE (EXCEPT APE) <i>Baboon</i> : Kammerer et al. 1995; <i>Rhesus Macaque</i> : NS Pope et al. 1989; A Black et al. 2001
No signif. difference				RODENT <i>Rat</i> : Vanderschueren et al. 1994* (femoral bone-cortical bone density)	
Females greater			RODENT <i>Rat</i> : DL DeMoss & Wright. 1998* (adolescent/adult skeletal mass & calcium content)	RODENT <i>Rat</i> : DL DeMoss & Wright 1998* (adolescent/adult skeletal mass & calcium content)	

1.3.2.2. Size of Skeletal Angles/Skeletal Structure/Skeletal Features

The quadriceps angle (Q angle) is determined by drawing one line from the anterior superior iliac spine through the center of the patella and a second line from the center of the patella through the tibial tuberosity. It is primarily affected by the width of the pelvis. As shown in Table 1.3.2.2, females have been found to have a more pronounced Q angle than males.

Table 1.3.2.2. Size of skeletal angles/skeletal structure/skeletal features.

Nature of Any Difference	Prepubertal				Postpubertal			
	Childhood				Adult			
Males larger/more pronounced								
No signif. diff.								
Females larger/more pronounced								

NORTH AMERICA *United States*: MG Horton & Hall 1989 (quadriceps angle); Csintalan et al. 2002:262 (quadriceps angle)

1.3.2.3. Size of Specific Bone and Cartilage Regions

Regarding bone and cartilage thus far investigated, those of male humans and amphibians have been found to be larger than those of females following puberty. One study of prepubertal mice reached the opposite conclusion (Table 1.3.2.3).

Table 1.3.2.3. Size of specific bone and cartilage regions.

Nature of Any Difference	Prepubertal				Postpubertal			
	Childhood				Adult			
Males larger/more pronounced								
No signif. diff.								
Females larger/more pronounced								

NORTH AMERICA *United States*: AT Rezcallah et al. 2001 (inner & outer pedicle widths of cervical 3-7)
AMPHIBIAN *Green Anole Lizard*: J Wade 1998 (2nd cerato branchial cartilage)

RODENT *Mouse*: T Iguchi et al 1989 (30 days old, pelvis longer & thinner)

1.3.2.4. Loss of Bone Density

Research has consistently shown that females lose more bone density with age than do males (Table 1.3.2.4). When this loss reaches such an extent that bones fracture easily, the condition is known as osteoporosis, an illness covered in Chapter 3.

Table 1.3.2.4. Loss of bone density.

Nature of Any Difference	Prepubertal				Postpubertal			
	Childhood				Adult			
Males higher								
No signif. diff.								
Females higher								

NORTH AMERICA *United States*: BL Riggs et al. 1981 (elderly, net bone loss); Ruff & Hayes 1983 (elderly, Pecos Pueblo Indian Tribe); Ruff & Hayes 1988 (elderly); SM Garn et al. 1992 (net bone loss); Duan et al. 2001a (elderly, vertebrae)
OCEANIA *Australia*: Feik et al. 1996; Duan et al. 2001b (net bone loss)

1.3.2.5. Bone-Specific Alkaline Phosphatase (Bone ALP)

Findings have been mixed with respect to any sex differences in the concentration of alkaline phosphatase in the bones (Table 1.3.2.5).

Table 1.3.2.5. Bone-specific alkaline phosphatase (bone ALP).

Nature of Any Difference	Prepubertal				Postpubertal			
	Childhood				Adult			
Males higher								
No signif. difference								
Females higher								

EUROPE *Greenland*: Minisola et al. 2002; Rejnmark et al. 2004
ASIA *China*: Yan et al. 2002 (elderly)

1.3.2.6. Joint Laxity

Joint laxity refers to the degree to which the joints are flexible. Studies have consistently shown such laxity to be greater in females than in males (Table 1.3.2.6).

Table 1.3.2.6. Joint laxity.

Nature of Any Difference	Sub-Adolescent		Postpubertal	
	Childhood	Adolescent	Adult	
Males higher				
No signif. difference				
Females higher	EUROPE <i>Sweden:</i> Jansson et al. 2003:1203*	EUROPE <i>Sweden:</i> LG Larsson et al. 1987; Jansson et al. 2003:1203*	AFRICA <i>Western Africa:</i> Beighton et al. 1973; Birrell et al. 1994 EUROPE <i>Britain:</i> N Hudson et al. 1995; <i>Sweden:</i> LG Larsson et al. 1993 MIDDLE EAST <i>Iraq:</i> Al-Rawi et al. 1985 (college) NORTH AMERICA <i>United States:</i> HA Bird et al. 1978; Jessee et al. 1980	

1.3.3. Skin

Variables pertaining to the skin include melanin levels, sun tanning rates, and the probability of being sun burned.

1.3.3.1. Skin Darkness (Melanin Index)

The darkness of human skin is primarily determined by the prevalence of melanin pigmentation. Numerous studies on gender differences in pigmentation have concluded that males have darker skin pigmentation than do females (Table 1.3.3.1).

Table 1.3.3.1. Skin darkness (melanin index).

Nature of Any Difference	Childhood	Postpubertal		Multiple Age Categories
		Adolescent	Adult	
Males	NORTH AMERICA <i>United States:</i> Relethford et al. 1985 (Irish ancestry)	AFRICA <i>Algeria:</i> Chamla & Demoulin 1978; <i>Ethiopia:</i> Harrison et al. 1969; <i>Nigeria:</i> Barnicot 1958 (Blacks); <i>South Africa:</i> Tobias 1961 (mulattos); Wassermann & Heyl 1968 ASIA <i>India:</i> Banerjee et al. 1983; <i>Tibet:</i> Kalla & Tiwari 1970 EUROPE <i>France:</i> Mesa 1983; <i>Greenland:</i> Thalbitzer 1914 (aboriginal); <i>Netherlands:</i> Rigters-Aris 1973 LATIN AMERICA <i>Bahamas:</i> Mazess 1967 (Blacks); <i>Brazil:</i> Harrison & Salzano 1966 (Guarni Indians); Harrison et al. 1967; <i>Mexico:</i> GW Lasker 1954 (Mestizos); Relethford & Lees 1981 (Tlaxcaltecas) MIDDLE EAST <i>Israel:</i> Hulse 1968 (Yemenite Jews) NORTH AMERICA <i>United States:</i> Hrdlicka 1922; EA Edwards & Duntley 1939; Garn et al. 1956; Pollitzer et al. 1970 (Seminole Indians); Harburg et al. 1978; JK Wagner et al. 2002:388 (Whites) OCEANIA <i>French Polynesia:</i> Harburg et al. 1982; <i>New Guinea:</i> P Clark et al. 1981 (twins); RG Harvey 1985 INTERNATIONAL <i>Various Middle Eastern Countries:</i> Sunderland 1979	AFRICA <i>South Africa:</i> JS Weiner et al. 1964 ASIA <i>Japan:</i> Mori & Tokuhashi 1956 (twins); Harvey & Lord 1978 (ainu); <i>Tibet:</i> Kalla 1973 EUROPE <i>Britain:</i> Kahlon 1976 (immigrants from India) LATIN AMERICA <i>Belize:</i> Byard & Lees 1982; <i>Ecuador:</i> Conway & Baker 1972 NORTH AMERICA <i>United States:</i> Sunderland & Woolley 1982 (immigrants from Wales) OCEANIA <i>Fujii:</i> Hyades & Deniker 1891 (postpubertals); <i>New Guinea:</i> RJ Walsh 1964 INTERNATIONAL <i>Various Pacific Islands:</i> RJ Walsh 1963	
No signif. difference			NORTH AMERICA <i>United States:</i> JK Wagner et al. 2002:388 (Hispanics & East Asians)	
Females				

1.3.3.2. Tanning of the Skin due to Sun Exposure

According to a few studies, males tan more readily than females do when their skin is exposed to the sun, although the differences have not always been found to be statistically significant (Table 1.3.3.2). Otherwise stated, most research has indicated that females exhibit greater skin reflectance than is true for males.

Table 1.3.3.2. Tanning of the skin due to sun exposure.

Nature of Any Difference	Postpubertal				Multiple Age Categories
				Adult	
Males more readily					ASIA <i>Korea</i> : Roh et al. 2001 LATIN AMERICA <i>Peru</i> : Conway & Baker 1972 (Quechua Indians) OCEANIA <i>Papua New Guinea</i> : RG Harvey 1985 INTERNATIONAL <i>Multiple Countries</i> : Tobias 1961
No signif. difference				EUROPE <i>Sweden</i> : Lock-Andersen et al. 1998 INTERNATIONAL <i>Multiple Countries</i> : Nordlund & Ortonne 1998	NORTH AMERICA <i>United States</i> : JK Wagner et al. 2002:388 (Whites, Hispanics, East Asians)
Females more readily					

1.3.3.3. Skin Color, Individual Variations in

According to two studies, males exhibit greater variation between individual variations in skin color than do females (Table 1.3.3.3).

Table 1.3.3.3. Skin color, individual variations in.

Nature of Any Difference	Postpubertal			
				Adult
Males more				LATIN AMERICA <i>Bahamas</i> : Mazess 1967 (Blacks) NORTH AMERICA <i>United States</i> : Pollitzer et al. 1970 (Seminole Indians)
No signif. difference				
Females more				

1.3.3.4. Skin Burning From Sun Exposure

One study of three racial/ethnic groups living in the United States concluded that females were more prone to sun burning than were males, although the differences were statistically significant only for Whites and Hispanics (Table 1.3.3.4).

Table 1.3.3.4. Skin burning from sun exposure.

Nature of Any Difference	Postpubertal			
				Adult
Males				
No signif. difference				NORTH AMERICA <i>United States</i> : JK Wagner et al. 2002:388 (East Asians)
Females				NORTH AMERICA <i>United States</i> : JK Wagner et al. 2002:388 (Whites & Hispanics)

1.3.3.5. Dewlap, Size of

The dewlap is a loose fold of skin hanging beneath the chin that is primarily found among various species of lizards. As shown in Table 1.3.3.5, the dewlap tends to be larger in males than in females.

1.3.3.5. Dewlap, size of.

Nature of Any Difference	Postpubertal			
				Adult
Larger in males				AMPHIBIAN <i>Anolis Carolinensis</i> : TA Jensen et al. 2000; <i>Green Anole Lizard</i> : J Wade 1998
No signif. difference				
Larger in females				

1.3.4. Other Organs and Structures

Over the years, quite a few studies have compared the size and various other aspects of the internal organs of males and females. Results are summarized below.

1.3.4.1. Adrenal Glands, Size of

Three studies in rodents all concluded that under a variety of conditions, larger adrenal glands were found in females than in males (Table 1.3.4.1).

Table 1.3.4.1. Adrenal glands, size of.

Nature of Any Difference					Multiple Age Categories
Larger in males					
No signif. difference					
Larger in females					RODENT Rat: Critchlow et al. 1963; Kitay 1963; Cowley & Griesel 1966 (resulting from prenatal protein deprivation)

1.3.4.2. Heart's Left Ventricle Wall, Size of

In both humans and rats, the left ventricle wall of the heart has been found to be thicker in females than in males (Table 1.3.4.2).

Table 1.3.4.2. Heart's left ventricle wall, size of.

Nature of Any Difference					Postpubertal
					Adult
Thicker in males					
No signif. difference					
Thicker in females					EUROPE Britain: P Douglas et al. 1995; Poland: Kostkiewicz et al. 1999 NORTH AMERICA United States: Dannenberg et al. 1989 (young); Giada et al. 1998 (young); JJ Morris et al. 1994; J Carroll et al. 1992 (elderly) RODENT Rat: Shreiner et al. 1969 (young); Schaibe & Scheuer 1984 (young); Malhotra et al. 1990 (young)

1.3.4.3. Inner Ear Structures, Size of

The inner ear helps to maintain balance. According to one study, males have inner ear structures that are larger than the same structures in females (Table 1.3.4.3). At least one study (Tremblay et al. 2004) indicated that this sex difference could help to explain why males are better than females at a spatial reasoning test called the rod-and-frame test, which requires subjects to position a rod vertically within a visual environment that is tilted (discussed in Chapter 5).

Table 1.3.4.3. Inner ear structures, size of.

Nature of Any Difference					Multiple Age Categories
Larger in males					NORTH AMERICA United States: Sato et al. 1992 (otolith & superior semicircular canal of the vestibular system)
No signif. difference					
Larger in females					

1.3.4.4. Pharynx, Size of

The pharynx is a fibromuscular tube that extends from the base of the skull to the throat (at which point it becomes the esophagus). One study found the pharynx of males to be larger than that of females (Table 1.3.4.4).

Table 1.3.4.4. Pharynx, size of.

Nature of Any Difference					Postpubertal
					Adult
Males larger					NORTH AMERICA United States: Mohsenin 2001
No signif. difference					
Females larger					

1.3.4.5. Anal-Genital Distance

Studies measuring the anal-genital distances of male and female rats show that males have a greater anal-genital distance than females (Table 1.3.4.5).

Table 1.3.4.5. Anal-genital distance.

Nature of Any Difference					Postpubertal
					Adult
Males larger					RODENT Rat: Dahlof et al. 1977; Faber & Hughes 1992; Keshet & Weinstock 1995
No signif. difference					
Females larger					

1.3.4.6. Kidney, Size of

One study compared the kidneys of male and female hamsters, and concluded that there were no differences in size (Table 1.3.4.6).

Table 1.3.4.6. Kidney, size of.

Nature of Any Difference	Postpubertal				
Males larger					
No signif. difference					RODENT Hamster: JM Feldman & Gerritson 1988 (diabetic, Chinese hamster)
Females larger					

1.3.4.7. Larynx, Vocal Cords/Tracks, Size of

While studies have found no significant sex differences in vocal cord size prior to adolescence, numerous studies have documented that the vocal cords are larger in males than females following puberty (Table 1.3.4.7).

Table 1.3.4.7. Larynx, vocal cords/tracks, size of.

Nature of Any Difference	Prepubertal			Postpubertal		Multiple Age Categories
	Infant	Early Childhood	Childhood	Adolescent	Adult	
Larger in males				EUROPE Britain: Cruttenden 1986 (following puberty)* NORTH AMERICA United States: Pedrey 1945; Klock 1968*; Kahane 1978*; Kahane 1980; Hirano et al. 1983*; Fitch & Giedd 1999* (vocal track); Lee et al. 1999 (vocal tracks); TL Perry et al. 2001* (following puberty)	EUROPE Britain: Crystal 1982 (vocal cords) NORTH AMERICA United States: Peterson & Barney 1952 (vocal tracks); Ladefoged & Broadbent 1957 (vocal tracks); Maue 1971; Laver & Trudgill 1979 (vocal tracks); Cruttenden 1986 (vocal cords); Titze 1989; Klatt & Klatt 1990; Ohde & Sharf 1992 (vocal cords); Tecumseh Fitch & Giedd 1999 (vocal tracks)	NORTH AMERICA United States: Tecumseh Fitch & Giedd 1999*
No signif. difference	NORTH AMERICA United States: Noback 1925; Negus 1929; Klock 1968*	NORTH AMERICA United States: Klock 1968*	EUROPE Britain: Cruttenden 1986 (in childhood)* NORTH AMERICA United States: Kahane 1978*; Hirano et al. 1983*; Fitch & Giedd 1999*; TL Perry et al. 2001* (in childhood)			
Larger in females						

1.3.4.8. Stiffness of Larynx

Two studies of the larynx concluded that females have a stiffer structure than do males (Table 1.3.4.8).

Table 1.3.4.8. Stiffness of larynx.

Nature of Any Difference	Multiple Age Categories				
Males larger					
No signif. difference					
Females larger					NORTH AMERICA United States: Netsell et al. 1991; Stathopoulos & Sapienza 1997

1.3.4.9. Liver, Size of

Most studies have concluded that the size of the liver in males is significantly larger than the liver in females (Table 1.3.4.9).

Table 1.3.4.9. Liver, size of.

Nature of Any Difference	Prepubertal		Postpubertal	
	Early Childhood		Adult	
Males larger	ASIA <i>Japan</i> : Tominga et al. 1995		ASIA <i>Japan</i> : Oshibuchi et al. 1991; Kawai et al. 1995 EUROPE <i>Italy</i> : Lonardo & Trande 2000	
No signif. difference			NORTH AMERICA <i>United States</i> : Kwo et al. 1998:1554 (young)	
Females larger				

1.3.4.10. Lung (Breathing) Capacity

Numerous studies have concluded that the lung capacity of the average male is significantly greater than that of the average female (Table 1.3.4.10).

Table 1.3.4.10. Lung (breathing) capacity.

Nature of Any Difference	Prepubertal		Postpubertal	
	Infant	Childhood	Adolescent	Adult
Males more	NORTH AMERICA <i>United States</i> : Tepper et al. 1986	NORTH AMERICA <i>United States</i> : JA Gilbert 1893:75*; JA Gilbert 1894*; JA Gilbert 1897*; FW Smedley 1902*	NORTH AMERICA <i>United States</i> : JA Gilbert 1893:75*; JA Gilbert 1894*; JA Gilbert 1897*; FW Smedley 1902*; Kanner et al. 1994*; DR Gold et al. 1996	EUROPE <i>Britain</i> : Britton et al. 1994 NORTH AMERICA <i>United States</i> : Kanner et al. 1994*
No signif. difference				
Females more				

1.3.4.11. Age of Reaching Maximum Lung Capacity

One study concluded that females reach their maximum lung capacity at significantly younger ages than did males (Table 1.3.4.11).

Table 1.3.4.11. Age of reaching maximum lung capacity.

Nature of Any Difference	Prepubertal		Postpubertal	
	Adolescent		Adult	
Males earlier				
No signif. difference				
Females earlier	NORTH AMERICA <i>United States</i> : Becklake & Kauffman 1999			

1.3.4.12. Mammary Glands, Size of

One study concluded that the mammary glands in the opossum were larger in females than in males from birth onward (Table 1.3.4.12).

Table 1.3.4.12. Mammary glands, size of.

Nature of Any Difference	Multiple Age Categories			
Larger in males				
No signif. difference				
Larger in females	MARSUPIAL <i>Opossum</i> : Renfree et al. 1990 (from birth through adolescence)			

1.3.4.13. Syrinx, Size of

The syrinx is the main anatomical source of song in bird species. It is the avian equivalent of the mammalian larynx (or voice box). As shown in Table 1.3.4.13, male zebra finches have larger syrinxes than do their female counterparts.

Table 1.3.4.13. Syrinx, size of.

Nature of Any Difference					Multiple Age Categories
Larger in males					BIRD <i>Zebra Finch</i> : Taber 1964; Luine et al. 1980; Adkins-Regan 1981; J Wade & Arnold 1996; Springer & Wade 1997; J Wade et al. 1999:143; Wade & Buhlman 2000 (syrinx & accompanying muscle fibers)
No signif. difference					
Larger in females					

1.3.4.14. Upper Airway Passages

According to the available evidence, males have larger upper airway passages than do females (Table 1.3.4.14).

Table 1.3.4.14. Upper airway passages.

Nature of Any Difference					Postpubertal Adult
Males larger					EUROPE <i>Britain</i> : Thurnheer et al. 2001 NORTH AMERICA <i>United States</i> : LJ Brooks & Strohl 1992; SE Martin et al. 1997
No signif. difference					
Females larger					

1.3.4.15. Pituitary Gland, Size of

Among rats, two studies concluded that females have a larger pituitary gland than do males (Table 1.3.4.15).

Table 1.3.4.15. Pituitary gland, size of.

Nature of the Relationship					Multiple Age Categories
Larger in males					
No signif. difference					
Larger in females					RODENT <i>Rat</i> : Critchlow et al. 1963; Kitay 1963

1.3.4.16. Electric Organ

Some species of fish are capable of emitting electrical impulses that disable prey or stun conspecific rivals. Studies that have compared the sexes with respect to the emissions of these impulses have reached different conclusions, depending on the exact measure of emission used (Table 1.3.4.16).

Table 1.3.4.16. Electric organ.

Nature of the Relationship					Postpubertal Adult
Males more					FISH <i>Electric Fish</i> : KD Dunlap et al 1997 (males longer pulse duration of electric organ discharge); KD Dunlap & Zakon 1998* (<i>Eigenmannia virescens</i> , pulse duration); KD Dunlap et al. 1998* (<i>Apteronotus albifrons</i> , electric organ discharge signals at lower frequencies); KD Dunlap et al. 1998* (<i>Apteronotus leptorhynchus</i> , number of chirps); KD Dunlap 2002 (<i>Apteronotus leptorhynchus</i> , chirps elicited by the presence of conspecifics); KD Dunlap 2002* (<i>Apteronotus leptorhynchus</i> , chirps at higher pitch measured as hertz frequency); KD Dunlap 2002* (<i>Apteronotus leptorhynchus</i> , number of chirps when a conspecific is present)
No signif. difference					FISH <i>Electric Fish</i> : KD Dunlap et al. 1998* (<i>Apteronotus albifrons</i> , number of electric organ discharge chirps)
Females more					FISH <i>Electric Fish</i> : CD Hopkins 1974 (<i>Sternopygus</i> , discharge frequency); KD Dunlap et al. 1997 (<i>Sternopygus</i> , discharge frequency); KD Dunlap & Zakon 1998* (<i>Eigenmannia virescens</i> , electric discharge hertz frequency)

1.4 BODILY SYSTEMS FUNCTIONING

Whereas in the preceding section, the focus was on structural aspects of the body, this section will concentrate on functional aspects of the body.

1.4.1. The Cardiovascular System

The cardiovascular system is comprised of the heart along with the arteries and veins that carry the blood throughout the body.

1.4.1.1. Blood Flow in General

The circulation of the blood throughout the cardiovascular system constitutes blood flow. Table 1.4.1.1 indicates that the blood flow of females surpasses that of males.

Table 1.4.1.1. Blood flow in general.

Nature of Any Difference					Postpubertal	
					Adult	
Higher in males						
No signif. difference						
Higher in females					EUROPE <i>Great Britain</i> : Centofanti et al. 2000 (pulsatile ocular blood flow) MIDDLE EAST <i>Israel</i> : Geyer et al. 2003 (pulsatile ocular blood flow) NORTH AMERICA <i>United States</i> : Gur et al. 1982 (in the cerebrum); Rodriguez et al. 1988 (in the cerebrum); Kastrup et al. 1999 (in the cerebrum); Gee et al. 2002 (pulsatile ocular blood flow)	

1.4.1.2. Blood Pressure in General

The pressure of the blood exerted on the walls of the arteries during the action of contraction (systolic) and relaxation (diastolic) of the heart is known as *blood pressure*. Table 1.4.1.2 indicates that very inconsistent gender differences have been found. Ultimately, age and ethnic factors may account for some of the inconsistencies, as may the distinction between systolic and diastolic blood pressure. Also worth mentioning is that in no case are the sex differences very substantial; studies that have reported statistically significant differences have usually been based on large samples (i.e., over 1000).

Table 1.4.1.2. Blood pressure in general.

Nature of Any Difference					Postpubertal		Multiple Age Categories
	Adolescent		Adult				
Higher in males					EUROPE <i>Britain</i> : Annandale & Hunt 1990:35; Pickering 1991 (before age 45, ambulatory); Dunnell et al. 1999* LATIN AMERICA <i>Brazil</i> : Dressler et al. 1998b:437 NORTH AMERICA <i>United States</i> : Fillingim & Maixner 1996; Singha et al. 2000 (with cocaine usage); Wang et al. 2002:255 RODENT <i>Rat</i> : Dubey et al. 2002		NORTH AMERICA <i>United States</i> : Alvarez 1923:18-19; Fillingim & Maixner 1996; Reckelhoff 2001 RODENT <i>Rat</i> : Bayorh et al. 2001:249
No signif. difference					AFRICA <i>South Africa</i> : Kaminer & Lutz 1960 (!Kung tribe) MIDDLE EAST <i>Iran</i> : LB Page et al. 1978 (Qash'gai tribe) NORTH AMERICA <i>United States</i> : E Boyle 1970 (Blacks) OCEANIA <i>New Guinea</i> : Maddocks 1967 RODENTS <i>Gerbils</i> : ED Hall et al. 1991 (blood flow prior & post ischemia)		LATIN AMERICA <i>Columbia</i> : Oliver et al. 1975 (among the Yanomomo)
Higher in females					NORTH AMERICA <i>United States</i> : Sontag 1947	EUROPE <i>Britain</i> : Dunnell et al. 1999* (elderly) NORTH AMERICA <i>United States</i> : SV Stone et al. 1990 (young, video games & smoking) OCEANIA <i>Solomon Islands</i> : LB Page et al. 1974 (rises more in females with age)	NORTH AMERICA <i>Canada</i> : Walters et al. 2002:687

1.4.1.8. Diastolic Blood Pressure

The pressure of the blood exerted on the walls of the arteries during the relaxed phase of heart contraction is known as diastolic blood pressure. Table 1.4.1.8 indicates that inconsistent gender differences have been found in diastolic blood pressure, perhaps due to age and ethnic influences.

Table 1.4.1.8. Diastolic blood pressure.

Nature of Any Difference	Prepubertal			Postpubertal		Multiple Age Categories
	Childhood	Adolescent	Adult			
Higher in males			EUROPE Britain: O Evans & Steptoe 2003:765 (medical school students, at rest) NORTH AMERICA United States: Fillingim & Maixner 1996; Fichera & Andreassi 2000:269 (arterial) OCEANIA New Guinea: Sinnott & Whyte 1973		EUROPE Germany: Bottner et al. 2004:4054*(ages 8 to 18)	
No signif. difference			NORTH AMERICA United States: Treiber et al. 2002:709 (young); Koertge et al. 2003:1320 (CAD patients); Aquilante et al. 2004:536 (varied results depending on dosage of dobutamine); Fillingim et al. 2005			
Higher in females	ASIA Japan: Kouda et al. 2003:1107* (older)	ASIA Japan: Kouda et al. 2003:1107*	NORTH AMERICA United States: E Boyle 1970 (Whites)		EUROPE Wales: Miall 1959	

1.4.1.9. Systolic Blood Pressure

The pressure of the blood exerted on the walls of the arteries during the action of contraction is known as systolic blood pressure. Table 1.4.1.9 indicates that the nature of any gender differences in systolic blood pressure have not revealed a clear pattern. This conclusion conflicts somewhat with a meta-analysis by Stoney et al. (1987) which concluded that males have higher systolic blood pressure than do females.

Table 1.4.1.9. Systolic blood pressure.

Nature of Any Difference	Prepubertal			Postpubertal		Multiple Age Categories
	Childhood	Adolescent	Adult			
Higher in males		ASIA Japan: Kouda et al. 2003:1107* (young)	EUROPE Britain: O Evans & Steptoe 2003:765 (medical school students, at rest) NORTH AMERICA United States: Wingard et al. 1983:167 (White); Fichera & Andreassi 2000:269 (arterial); Treiber et al. 2002:709 (young)		EUROPE Germany: Bottner et al. 2004:4054*(ages 8 to 18)	
No signif. difference			NORTH AMERICA United States: Koertge et al. 2003:1320 (CAD Patients) OCEANIA New Guinea: Sinnott & Whyte 1973			
Higher in females	ASIA Japan: Kouda et al. 2003:1107* (older)		AFRICA South Africa: Truswell et al. 1972 (with age, !Kung tribe) NORTH AMERICA United States: SR Barnett et al. 1999:1098; Aquilante et al. 2004:536 (when administered dobutamine)			

1.4.1.10. Pulse Rate

The rate at which the heart pulsates (rhythmic beats) per minute is known as pulse rate. One study found females exhibited higher pulse rates rather than men (Table 1.4.1.10).

Table 1.4.1.10. Pulse rate.

Nature of Any Difference	Multiple Age Categories					
Higher in males						
No signif. difference						
Higher in females						NORTH AMERICA United States: Aronson & Burger 2000

1.4.1.11. Heart Rate in General

Sex differences in heart rates appear to vary by age, with most studies finding no differences in childhood. According to the studies reviewed in Table 1.4.1.11, following puberty, most studies have found females exhibiting higher heart rates than males under most testing conditions. This conclusion essentially concurs with a meta-analysis conducted by Stoney et al. (1987).

Table 1.4.1.11. Heart rate in general.

Nature of Any Difference	Prepubertal				Postpubertal	
	Fetal Stage	Infant	Toddler	Childhood	Adolescent	Adult
Males faster					ASIA <i>Russia</i> : Anishchenko et al. 2001	
No signif. difference	NORTH AMERICA <i>United States</i> : J Bernard 1964; Fleisher et al. 1997 (fetus); Genuis et al. 1996 (fetus)	EUROPE <i>Italy</i> : Stamba-Badiale et al. 1997; <i>Hungary</i> : Nagy et al. 2000 NORTH AMERICA <i>United States</i> : JM Richards et al. 1984*	NORTH AMERICA <i>United States</i> : JM Richards et al. 1984*	NORTH AMERICA <i>United States</i> : Frodi & Lamb 1978 (in response to crying babies); Rowland et al. 2000 (maximal heart rate; arterial venous oxygenation differences)		EUROPE <i>Britain</i> : Coventry & Hudson 2001:874 (baseline and while gambling) NORTH AMERICA <i>United States</i> : TG Power et al. 1982*: (heart rate acceleration in response to smiling infants) OCEANIA <i>Australia</i> : AS Jordan et al. 2004:997 (resting)
Females faster		EUROPE <i>Hungary</i> : Nagy et al. 2000 NORTH AMERICA <i>United States</i> : CW Townsend 1887		NORTH AMERICA <i>United States</i> : W Pearl 1996; MT Allen & Matthews 1997* (base line heart rate)	NORTH AMERICA <i>United States</i> : MT Allen & Matthews 1997* (base line heart rate)	EUROPE <i>Britain</i> : Eynde & Ostyn 1986 (after physical exercise); O Evans & Steptoe 2003:765 (medical school students) NORTH AMERICA <i>United States</i> : Bazett 1920 (resting heart rate, Winborn et al. 1988 (after physical exercise); SV Stone et al. 1990 (young, video games, & smoking); Koltyn et al. 1991 (after swimming); Sharpley 1994 (base line heart rate); PK Stein et al. 1997; SR Barnett et al. 1999:1198 (beats per minute); Fichera & Andreassi 2000:269; Pham & Rosen 2002 (higher resting heart rate); Koertge et al. 2003:1320 (CAD patients)

1.4.1.12. Increase in Heart Rate

A couple of studies have looked at heart rate increases in response to various stimuli but reached inconsistent conclusions (Table 1.4.1.12).

Table 1.4.1.12. Increase in heart rate.

Nature of Any Difference	Postpubertal					
						Adult
Males greater						NORTH AMERICA <i>United States</i> : Cantor et al. 1978 (when viewing violent movie scenes)
No signif. difference						
Females greater						NORTH AMERICA <i>United States</i> : TG Power et al. 1982*: (heart rate acceleration in response to crying infants)

1.4.1.13. Heart Rate, Within Individual Variability in

Most studies have found males exhibiting greater variability in heart rates than is true for females (Table 1.4.1.13).

Table 1.4.1.13. Heart rate, within individual variability in.

Nature of Any Difference	Postpubertal				Multiple Age Categories
				Adult	
Males greater				NORTH AMERICA <i>United States</i> : Stein et al. 1997	EUROPE <i>Netherlands</i> : Ramaekers et al. 1998 NORTH AMERICA <i>United States</i> : MJ Cowan et al. 1994; Bigger et al. 1995; Umetani et al. 1998
No signif. difference					NORTH AMERICA <i>United States</i> : Aronson & Burger 2000
Females greater				NORTH AMERICA <i>United States</i> : SM Ryan et al. 1994 (in high-frequency heart rate subjects); Liao et al. 1995 (in high frequency heart-rate subjects); Huikuri et al. 1996 (in high frequency heart-rate subjects)	

1.4.1.14. Aggregation of Blood Platelets

Three studies of rodents have indicated that males have more aggregation of blood platelets than is true for females (Table 1.4.1.14).

Table 1.4.1.14. Aggregation of blood platelets.

Nature of Any Difference	Postpubertal			
				Adult
Males greater				RODENT Rat: Emms & Lewis 1985; Morikawa et al. 1985; Kojima et al. 1993
No signif. difference				
Females greater				

1.4.1.15. QT Intervals

Heart beats can be monitored on an electrocardiogram (EKG) and described in terms of points when they shift in direction. These points are known as Q and T . Studies have sought to determine if the time intervals (described in milliseconds) differ according to gender. Table 1.4.1.15 indicates that the average interval is longer for females than for males.

Table 1.4.1.15. QT intervals.

Nature of Any Difference	Prepubertal		Postpubertal	
	Childhood	Adolescent	Adult	
Males longer				
No signif. difference	NORTH AMERICA Canada: Rautaharju et al. 1992*; United States: Pearl 1996*			
Females longer	NORTH AMERICA United States: Makkar et al. 1993; JH Burke et al. 1997; Locati et al. 1998		NORTH AMERICA United States: Pearl 1996*	EUROPE Italy: Stramba-Badiale et al. 1997; Netherlands: Conrath et al. 2002 (patients with long QT syndrome) NORTH AMERICA Canada: Rautaharju et al. 1992*; United States: Merri et al. 1989; Hashiba 1992; Makkar et al. 1993; JH Burke et al. 1997; Lehmann et al. 1997

1.4.1.16. P-R Interval

The P-R interval refers to the time lapse between the beginning of a P-wave and the start of the QRS complex seen on an electrocardiogram. One study concluded that this interval on average is significantly greater for males than for females (Table 1.4.1.16).

Table 1.4.1.16. P-R interval.

Nature of Any Difference	Postpubertal			
				Adult
Longer in males				NORTH AMERICA United States: SR Barnett et al. 1999:1098
No signif. difference				
Longer in females				

1.4.1.17. Ta-e Interval

The Ta-e interval is the length of time (in milliseconds) between the T spike of a heart beat and the end of the heart beat cycle. Studies suggest that, on average, this interval is slightly longer for males than for females (Table 1.4.1.17).

Table 1.4.1.17. Ta-e interval.

Nature of Any Difference	Prepubertal			
				Childhood
Longer in males				EUROPE Britain: Smetana et al. 2003 ASIA Japan: Nakagawa et al. 2003; Nakagawa et al. 2004
No signif. difference				
Longer in females				

1.4.1.18. Vagal Tone, Variations in

Vagal tone is associated with the cardiovascular system and the vagus nerve. As shown in Table 1.4.1.18, males have been shown to exhibit more distinct variations in vagal tone than females.

Table 1.4.1.18. Vagal tone, variations in.

Nature of Any Difference	Prepubertal	
	Childhood	
More in males	ASIA Japan: Nakagawa et al. 2003; Nakagawa et al. 2004 EUROPE Britain: Smetana et al. 2003 NORTH AMERICA United States: Elsenbruch et al. 1999 (greater decreased vagal tones of the heart rate while awake)	
No signif. difference		
More in females		

1.4.1.19. Vascular Constriction

Vascular constriction refers to the narrowing of the blood vessels. One study concluded that such constriction was greater in male than female rats following the consumption of salt (Table 1.4.1.19).

Table 1.4.1.19. Vascular constriction.

Nature of Any Difference	Postpubertal	
	Adult	
Males more	RODENT Rat: LA Barron et al. 2002 (caused by sodium intake)	
No signif. difference		
Females more		

1.4.1.20. Content of the Blood (Except Hormones)

A few studies have compared males and females with respect to the mineral, metal, and electrolyte content of the blood. As shown in Table 1.4.1.20, lead and potassium have been found to be higher in the blood of males, while cobalt, copper, calcium, and phosphate were higher in the blood of females.

Table 1.4.1.20. Content of the blood (except hormones).

Nature of Any Difference	Postpubertal	
	Adolescent	Adult
Higher in males	EUROPE Sweden: Barany et al. 2002* (lead) NORTH AMERICA United States: Wysowski et al. 2003* (serum potassium concentration)	NORTH AMERICA United States: Wysowski et al. 2003* (serum potassium concentration)
No signif. difference		
Higher in females	EUROPE Sweden: Barany et al. 2002* (cobalt, copper)	ASIA China: Yan et al. 2002 (elderly, osteocalcin, calcium and phosphate concentrations)

1.4.2. The Immune System

The immune systems of males and females are different, a conclusion that is inescapable when one considers the rates at which males and females contract various immune disorders (see Chapter 3). Here the results of a limited number of studies that have explored sex differences in the immune system are reviewed.

1.4.2.1. Immune (Antibody) Response in General

When the body is invaded by viruses or bacteria, one response of the immune system is to release antibodies that attempt to surround and kill the invaders. Table 1.4.2.1 indicates that this tendency is usually stronger for females than for males, both in humans and in rodents.

Table 1.4.2.1. Immune (antibody) response in general.

Nature of Any Difference					Postpubertal	Multiple Age Categories
					Adult	
Males stronger					RODENT <i>Meadow Vole</i> : S L Klein et al. 1997* (when pair housed)	
No significant difference					RODENT <i>Meadow Vole</i> : S L Klein et al. 1997* (when pair housed)	
Females stronger					RODENT <i>Mouse</i> : Y Weinstein et al. 1984 (thymocyte & lymphocyte responses to antigens); <i>Rat</i> : Grossman 1985; Grossman & Roselle 1986; <i>Prairie Vole</i> : S L Klein et al. 1997* (when pair housed)	NORTH AMERICA <i>United States</i> : Rhodes et al. 1969 (brucella); Michaels & Rogers 1971 (E coli); Patty et al. 1976 (measles); London & Drew 1977 (hepatitis); MJ Spencer et al. 1977 (rubella)

1.4.2.2. Allograft Rejection

An allograft refers to tissue transplanted from one individual to another (assuming they are members of the same species). One study concluded that allografts are more often rejected by the bodies of females than by those of males (Table 1.4.2.2).

Table 1.4.2.2. Allograft rejection.

Nature of Any Difference					Postpubertal
					Adult
Males more					
No significant difference					
Females more					NORTH AMERICA <i>United States</i> : Graff et al. 1969

1.4.2.3. Immunoglobulin-M (IgM) Level

The secretion of Immunoglobulin-M (IgM) is the immune system's first response to microbial invasion, and thus plays a critical role in maintaining health. Females have been shown to have higher levels of IgM than do males (Table 1.4.2.3).

Table 1.4.2.3. Immunoglobulin-M (igm) level.

Nature of Any Difference					Prepubertal	Multiple Age Categories
					Childhood	
Male levels higher						
No signif. difference						
Female levels higher					EUROPE <i>Britain</i> : Butterworth et al. 1967	NORTH AMERICA <i>United States</i> : K Rhodes et al. 1969

1.4.2.4. Immunoglobulin-E (IgE) Response to Foreign Microbial Invasion

Immunoglobulin-E (IgE), like IgM, is important in warding off microbial invaders. One study of rats indicates that females exhibited a stronger IgE response to invading bacteria than did males (Table 1.4.2.4).

Table 1.4.2.4. Immunoglobulin-E (ige) response to foreign microbial invasion.

Nature of Any Difference					Multiple Age Categories
Stronger in males					
No signif. difference					
Stronger in females					RODENT <i>Rat</i> : Astoquiza et al. 1991

1.4.2.5. Immunological Responsiveness to GnRH

One study of immune system responses to GnRH (gonadotropin-releasing hormone) among rats concluded that this hormone was stronger among females than among males (Table 1.4.2.5).

Table 1.4.2.5. Immunological responsiveness to GnRH.

Nature of Any Difference					Postpubertal
					Adult
Stronger in males					
No signif. difference					
Stronger in females					RODENT <i>Rat</i> : TL Morton et al. 2003

1.4.2.6. Islet Cell Autoantibodies

Islet cell autoantibodies (ICAs) are important in health maintenance, especially with regarding resistance to Type 1 diabetes. According to the one located study, males have greater ICAs than do females (Table 1.4.2.6).

Table 1.4.2.6. Islet cell autoantibodies.

Nature of Any Difference					Postpubertal
					Adult
Males have more					EUROPE <i>Finland</i> : Krischer et al. 2004 (ICAs)
No signif. difference					
Females have more					

1.4.2.7. Serum Bilirubin Levels

Serum bilirubin levels appear to protect against colorectal cancer. Two studies concluded that levels of serum bilirubin are higher among males than among females (Table 1.4.2.7).

Table 1.4.2.7. Serum bilirubin levels.

Nature of Any Difference					Postpubertal
					Adult
Male levels higher					NORTH AMERICA <i>United States</i> : Manolio et al. 1992; SD Zucker et al. 2004
No signif. difference					
Female levels higher					

1.4.2.8. T-Cell Ratio

T-cells are any of several lymphocytes that form in the thymus and have the ability to recognize specific peptide antigens, or the proteins of microscopic invaders. According to one study, females have higher T-cell ratios or exhibit stronger T-cell response to antigens than do males (Table 1.4.2.8).

Table 1.4.2.8. T-cell ratio.

Nature of Any Difference					Postpubertal
					Adult
Males levels higher					
No signif. difference					
Females levels higher					EUROPE <i>Italy</i> : Amadori et al. 1995 (CD4/CD8 T-cell ratio)

1.4.2.9. T-Cell Reactivity

T-cells are any of several lymphocytes that form in the thymus and have the ability to recognize specific peptide antigens. According to one study, females have higher T-cell reactivity to immunodominant PLP peptides than do males (Table 1.4.2.9).

Table 1.4.2.9. T-cell reactivity.

Nature of Any Difference					Postpubertal
					Adult
Males levels higher					
No signif. difference					
Females levels higher					OCEANIA <i>Australia</i> : Greer et al. 2004

1.5 BASIC BODILY FUNCTIONING

Bodily functioning covers a broad range of internal processes that are constantly changing throughout the lives of organisms.

1.5.1. Metabolic Process

Metabolic processes have to do with how quickly foods and other substances are absorbed and utilized by the body.

1.5.1.1. Protein Intake

One study of rats indicates that males consumed higher proportions of their diet in the form of protein than was the case for females (Table 1.5.1.1).

Table 1.5.1.1. Protein intake.

Nature of the Relationship					Postpubertal
					Adult
Males consume more					RODENT Rat: Leshner & Collier 1973 (young, protein to non-protein consumption ratio)
No signif. difference					
Females consume more					

1.5.1.2. Gastric Emptying/Rate of Bowel Movements

The speed with which unabsorbed portions of consumed food pass through the intestines and are expelled from the body is known as the rate of *gastric emptying*. In recent years, the measurement of gastric emptying has largely relied on asking subjects to consume a radioactive substance that is later detected in the urine and feces (Sadik et al. 2003:37). A closely related concept is termed *colonic transit speed* (Meier et al. 1995). As shown in Table 1.5.1.2, most studies have found that males expel solid waste at a higher average rate than is true for females while there are no significant differences in the expulsion of liquid waste by the small intestine.

Table 1.5.1.2. Gastric emptying/rate of bowel movements.

Nature of the Relationship					Postpubertal	Multiple Age Categories
					Adult	
Males more rapid					ASIA Singapore: LY Chen et al. 2000 (more frequent bowel movements) EUROPE Sweden: Hermansson & Sivertsson 1996 (large intestines) NORTH AMERICA United States: AM Metcalf et al. 1987 (colonic transit); Abrahamsson et al. 1988 (colonic transit); R Meier et al. 1995 (colonic transit); J Hamilton & Yonkers 1996 (females more reduced rate); Tougas et al. 2000 (large intestines); Teff et al. 1999 (liquids and solids)	EUROPE Sweden: Stotzer et al. 1999 (large intestines); Sadik et al. 2003 (large & small intestines)
No signif. difference					EUROPE Netherlands: Bennink et al. 1999 (small intestines) NORTH AMERICA United States: Madsen 1992 (small intestines); Argenyi et al. 1995 (small intestines)	
Females more rapid						

1.5.1.3. Gastric Acidity

According to two studies, females have greater acidity in the stomach than do males (Table 1.5.1.3).

Table 1.5.1.3. Gastric acidity.

Nature of the Relationship					Postpubertal
					Adult
Males more					
No signif. difference					
Females more					NORTH AMERICA United States: M Grossman et al. 1963; J Hamilton & Yonkers 1996

1.5.1.4. Circadian Rhythm/Phase

No consistent conclusion has been reached regarding any gender differences in circadian rhythms or phases (Table 1.5.1.4).

Chapter 2

THE BRAIN AND BIOCHEMISTRY

This chapter summarizes research findings on gender differences in brain structures and functioning as well as in all aspects of biochemistry. Because the biochemistry of the brain and the body are exceedingly complex and dynamic, many of the topics covered in this chapter are highly detailed and technical. Another reason for the technical nature of this chapter involves the fact that males and females of most species differ in body size. Some studies adjust for body size when comparing different aspects of the brain, or different amounts of various biochemicals, while others do not. Also, sometimes biochemical sex differences will be found in one part of the body but not in others. These nuances are noted when relevant.

2.1 THE NERVOUS SYSTEM

The central nervous system (CNS) consists of the brain and spinal cord. The peripheral nervous system (PNS) involves all nerve processes found outside the CNS. The CNS and PNS essentially guide and coordinate nearly all of the functioning of the rest of the body.

2.1.1. General Physical Brain Characteristics

Research findings regarding basic physical characteristics of the brain are reviewed below. They pertain to the overall size of the brain as well as the composition of various subcomponents.

2.1.1.1. Head Circumference and Cranial Capacity

Simply measuring the circumference of the head provides a crude measure of brain size and has been used for this purpose for many years. This crude method of measuring cranial capacity involved filling an empty skull with sand small pellets and assessing the cubic centimeters displaced by this material in a measuring beaker. As shown in Table 2.1.1.1, studies have revealed that for all age groups, males have larger head circumferences and cranial capacities than do females. None of these studies adjusted for sex differences in body weight.

Table 2.1.1.1. Head circumference and cranial capacity.

Nature of Any Difference	Prepubertal				Postpubertal	
	Infant	Toddler	Early Childhood	Childhood	Adolescent	Adult
Larger in males	NORTH AMERICA <i>United States:</i> LE Holt 1897 (neonate); DB Gardner & Swiger 1958 (neonate, adoptees); Alomli et al. 2001:256 (neonate)	NORTH AMERICA <i>United States:</i> LE Holt 1897; Eichorn & Bailey 1962*	NORTH AMERICA <i>United States:</i> Eichorn & Bailey 1962*; Rocha & Malina 1983:466*	NORTH AMERICA <i>United States:</i> Eichorn & Bailey 1962*; Rocha & Malina 1983:466*	NORTH AMERICA <i>United States:</i> Eichorn & Bailey 1962*; Rocha & Malina 1983:466*	NORTH AMERICA <i>United States:</i> Eichorn & Bailey 1962*; DeCarli et al. 2005 (cranial capacity)
No signif. difference						
Larger in females						

2.1.1.2. Brain Size/Brain Weight/Brain Volume

According to Table 2.1.1.2, human males have larger brains than do females. This conclusion is consistent with generalizations reached by Swaab and Hoffman (1984) and by Lynn (1999), while it is inconsistent with Halpern's (1992:140) assertion that no significant sex difference in brain size has been documented. Some of the studies cited in Table 2.1.1.2 made adjustments for body size. Doing so reduced the brain size difference by about half, but male brains were still significantly larger. So far, only three studies have involved species other than humans. The one involving rhesus monkeys found male brains larger, while the two studies of rodents found no significant sex difference.

Table 2.1.1.2. Brain size/brain weight/brain volume.

Nature of Any Difference	Prepubertal			Postpubertal		Multiple Age Categories
	Infant	Early Childhood	Childhood	Adolescent	Adult	
Larger in males	EUROPE <i>Germany:</i> Waldeyer 1908 NORTH AMERICA <i>United States:</i> Janowsky 1989	EUROPE <i>Netherlands:</i> Swaab & Hofman 1984* (adjusted for body weight)	NORTH AMERICA <i>United States:</i> Burt & Moore 1912; Giedd et al. 1996*; Castellanos et al. 2002:1746* (unadjusted for body size)*	NORTH AMERICA <i>United States:</i> Burt & Moore 1912; Giedd et al. 1996*; Castellanos et al. 2002:1746* (unadjusted for body size)*	EUROPE <i>Netherlands:</i> Swaab & Hofman 1984* (adjusted for body weight) NORTH AMERICA <i>Canada:</i> Ankey 1992 (adjusted for body size); <i>United States:</i> Dekaban & Sadowsky 1978 (throughout adult life); Kretschmann et al. 1979 (height controlled); Zetz et al. 1982; Rushton 1992 (adjusted for body size); SM Breedlove 1994 (adjusted for height differences); Cowell et al. 1994; Filipek et al. 1994 (young); Schlaepfer et al. 1995 (brain volume); M Peters et al. 1998; Nopoulos et al. 2000 (young); JS Allen et al. 2002; Byne et al. 2001 (brain weight); DeCarli et al. 2005 PRIMATE (EXCEPT APE) <i>Rhesus Macaques:</i> D Folk et al. 1999	EUROPE <i>Denmark:</i> Holloway 1980 (throughout life); <i>Estonia:</i> Lynn et al. 2000 (7-18 year olds) NORTH AMERICA <i>United States:</i> Mall 1909; Dekaban & Sadowski 1978; Ho et al. 1980; R Lynn 1993 (adjusted for body size); Filipek et al. 1994 (whole brain volume); Pfefferbaum et al. 1994; Blatter et al. 1995; Flaum et al. 1995 (among schizophrenics); Nopoulos et al. 2000; Rushton et al. 2000
No signif. difference					NORTH AMERICA <i>United States:</i> Ho et al. 1980 (adjusted for body size) RODENT <i>Mouse:</i> Koshibu et al. 2004 (C57Bl/6J strain, 3-D MRI); <i>Rat:</i> Madeira et al. 1991 (Sprague-Dawley rats)	
Larger in females			NORTH AMERICA <i>United States:</i> A Reiss et al. 2004 (among children born prematurely)			

2.1.1.3. Brain Growth Rate

One study of rats concluded that male brains grow at a faster rate than female brains during the latter portion of gestation and into the first few days following birth (Table 2.1.1.3).

Table 2.1.1.3. Brain growth rate.

Nature of Any Difference	Citation
More rapid in males	RODENT <i>Rat:</i> Ryzhavskaia & Biriukova 1993 (embryonic day 21 through postnatal day 5, brain mass)
No signif. difference	
More rapid in females	

2.1.1.4. Size of the Brain Ventricles

Ventricles are the fluid-filled cavities within the brain. Findings have been mixed with respect to any sex differences in the volume of these ventricles, although most studies of humans suggest that males have somewhat larger ventricles (Table 2.1.1.4).

Table 2.1.1.4. Size of brain ventricles.

Nature of Any Difference	Prepubertal		Postpubertal	
	Childhood	Adolescent	Adult	
Larger in males	NORTH AMERICA <i>United States</i> : Reiss et al. 1996 (total volume); Eliez et al. 2001 (3 rd ventricle, persons with fragile X syndrome)	MIDDLE EAST <i>Turkey</i> : Celik et al. 1995* (3 rd ventricle, CT scan) NORTH AMERICA <i>United States</i> : Giedd et al. 1996 (total volume)	MIDDLE EAST <i>Turkey</i> : Celik et al. 1995* (3 rd ventricle, CT scan) NORTH AMERICA <i>United States</i> : DeCarli et al. 2005 (lateral ventricle and temporal horn of lateral ventricles)	
No signif. difference		MIDDLE EAST <i>Turkey</i> : Celik et al. 1995* (lateral ventricles, CT scan)	MIDDLE EAST <i>Turkey</i> : Celik et al. 1995* (lateral ventricles, CT scan) RODENT <i>Mouse</i> : Koshibu et al. 2004* (3 rd ventricle, 3-D MRI, C57Bl/6J strain)	
Larger in females			RODENT <i>Mouse</i> : Koshibu et al. 2004* (lateral ventricles, 3-D MRI, C57Bl/6J strain)	

2.1.1.5. Ratio of Gray-to-White Matter

White matter consists of neuronal axons with a fatty or white nerve covering called myelin that speeds up the passage of signals. Gray matter is composed of neuronal axons without myelin. Except for a couple of studies reporting no significant sex differences, research has repeatedly shown that the ratio of gray-to-white matter is higher in males than in females (Table 2.1.1.5).

Table 2.1.1.5. Ratio of gray-to-white matter.

Nature of Any Difference	Prepubertal		Postpubertal	
	Childhood	Adolescent	Adult	
Males higher		EUROPE <i>Switzerland</i> : Rabinowicz et al. 2002	NORTH AMERICA <i>Canada</i> : Witelson 1989; <i>United States</i> : LS Allen & Gorski 1987; Filipek et al. 1994 (young); Schlaepfer et al. 1995 (in the prefrontal cortex and superior-temporal gyrus); Passe et al. 1997; M Peters et al. 1998; Gur et al. 1999 (young); Highley et al. 1999; Nopoulos et al. 2000; JM Goldstein et al. 2001; JS Allen et al. 2003 (in the cerebrum); RJ Haier et al. 2005	
No signif. difference	NORTH AMERICA <i>United States</i> : AL Reiss et al. 1996		NORTH AMERICA <i>United States</i> : Schlaepfer et al. 1995 (young, in the parietal lobe)	
Females higher				

2.1.1.6. Volume of White Matter in the Brain

Two studies have concluded that males have more white matter in the brain than do females (Table 2.1.1.6).

Table 2.1.1.6. Volume of white matter in the brain.

Nature of Any Difference	Prepubertal		Postpubertal	
	Childhood	Adolescent	Adult	
Males higher			NORTH AMERICA <i>United States</i> : Filepek et al. 1994 (in the neocortex); Gur et al. 1999	
No signif. difference				
Females higher				

2.1.1.7. Myelination

According to one study of rats, females exhibited greater myelination of axons in the corpus callosum following environmental enrichment experiences than did males (Table 2.1.1.7). In the genu region of the corpus callosum, females had more unmyelinated axons, but fewer myelinated axons than males.

Table 2.1.1.7. Myelination.

Nature of Any Difference	Prepubertal		Postpubertal	
	Infant		Adult	
Males			RODENT Rat: Mack et al. 1995* (genu region in Purdue-Wistar rats; number of myelinated axons)	
No signif. difference	MARSUPIAL <i>Gray Opossum:</i> LeBlond & Cabana 1997 (birth to 7 weeks of age, C8 & L4 roots of the spinal cord)		RODENT Rat: Juraska & Kopcik 1988* (of axons in the posterior corpus callosum, reared in a deprived environment)	
Females			RODENT Rat: Juraska & Kopcik 1988* (of axons in the posterior corpus callosum, reared in a complex environment); Mack et al. 1995* (number of unmyelinated axons and ratio of myelinated to unmyelinated axons in the genu region of the corpus callosum of Purdue-Wistar rats)	

2.1.2. Neocortical Size (Except When Lateralized)

The neocortex is the primary portion of the human brain that is most highly developed in humans. In other words, when comparing the human brain to that of, say, the chimpanzee, the size and shape of the structures are nearly identical except in the case of the neocortex. The human neocortex is nearly four-times greater than that of chimpanzees.

2.1.2.1. Neocortex (Cerebrum) in General, Size of

Most studies, at least among humans, have indicated that the neocortex is larger among males than among females. However, the one study that adjusted for the fact that male brains as a whole are larger concluded that proportionally the size of the male neocortex and that of the female are equivalent (Table 2.1.2.1).

Table 2.1.2.1. Neocortex (cerebrum) in general, size of.

Nature of Any Difference	Prepubertal		Postpubertal		Multiple Age Categories
	Infant	Childhood	Adult		
Greater in males	RODENT Rat: Ryzhavsikii & Birivkova 1993 (postnatal day 5, thickness)	NORTH AMERICA United States: JN Giedd et al. 1997 (volume); Rabinowicz et al. 1999	NORTH AMERICA Canada: Witelson et al. 1995; United States: Filipek et al. 1994*; Passe et al. 1997; Nopoulos et al. 2000; Goldstein et al. 2001; Allen et al. 2002 RODENT Mouse: Markham et al. 2003 (thicker in the limb control area, the somatosensory area, & the posterior parietal area); Rat: SN Reid & Juraska 1992 (longer & wider)		NORTH AMERICA United States: MC Diamond et al. 1979; Henery & Mayhew 1989; Cowell et al. 1994; Pakkenberg & Gundersen 1997; Raz et al. 1998
No signif. difference			NORTH AMERICA United States: Filipek et al. 1994:352* (relative to the brain size as a whole)		
Greater in females					RODENT Rat: Juraska 1990 (thickness)

2.1.2.2. Frontal Lobes, Size of

The frontal lobes are a prominent part of the neocortex, comprising nearly a third of its total volume. These lobes play an important part in the intellectual tasks requiring long-term planning, impulse control, and even moral reasoning.

2.1.2.2a. Frontal Lobes, Overall Size of

As shown in Table 2.1.2.2, most studies have concluded that males have slightly but significantly larger frontal lobes than do females. It should be pointed out, however, that males have larger brains as a whole (and larger bodies as well). If controls were introduced for these latter findings, most if not all of the sex difference in frontal lobe size may be eliminated.

Table 2.1.2.2. Frontal lobes, overall size of.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					NORTH AMERICA <i>United States</i> : Nopoulos et al. 2000; JM Goldstein et al. 2001; JS Allen et al. 2002; DeCarli et al. 2005
No signif. difference					NORTH AMERICA <i>United States</i> : Cowell et al. 1994
Larger in females					

2.1.2.2b. Frontal Lobes, Size of Subcomponents

According to one study, the size of the orbital frontal cortex, a subcomponent of the frontal lobes, is larger in women than in men (Table 2.1.2.2b). However, not all subcomponents of the frontal cortex show sex differences.

Table 2.1.2.2b. Frontal lobes, size of subcomponents.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					
No signif. difference					NORTH AMERICA <i>United States</i> : Bryant et al. 1999 (prefrontal cortex); Gur et al. 2002* (dorsal prefrontal cortex)
Larger in females					NORTH AMERICA <i>United States</i> : Gur et al. 2002* (orbital frontal cortex)

2.1.2.3. Parietal Lobe, Size of

The parietal lobes are part of each hemisphere and are located between the frontal lobes and the occipital lobes. Functionally, the parietal lobes appear to be primarily involved in interpreting sensory information having to do with touch and physical pain. However, these lobes also seem to play an important role in eye-hand coordination. Two studies have indicated that a lower portion of the left parietal lobe in males is larger than is the case for females after adjusting for sex differences in overall brain size, while one study failed to document a statistically significant difference (Table 2.1.2.3).

Table 2.1.2.3. Parietal lobe, size of.

Nature of Any Difference					Postpubertal	Multiple Age Categories
					Adult	
Males larger on the left						NORTH AMERICA <i>United States</i> : DN Kennedy et al. 1998 (inferior portion); Frederikse et al. 1999 (inferior portion)
No signif. difference					NORTH AMERICA <i>United States</i> : DeCarli et al. 2005	
Females larger on the left						

2.1.2.4. Postcentral Sulcus Extension Into the Sylvian Fissure, Length of

The postcentral sulcus extension into the Sylvian fissure is a part of the parietal lobes. Two studies indicate that this extension is longer in the brains of males relative to those of females (Table 2.1.2.3).

Table 2.1.2.4. Postcentral sulcus extension into the Sylvian fissure, length of.

Nature Any Difference					Multiple Age Categories
More continuous in males					LATIN AMERICA <i>Chile</i> : Ide et al. 1996 (in the left hemisphere); Ide & Aboitiz 2001 (in the left hemisphere)
No signif. Difference					
More continuous in females					

2.1.2.5. Occipital Lobe, Size of

The occipital lobes are located at the back of the brain and are involved in vision. The single study cited shows no overall sex difference in the size of the occipital lobes (Table 2.1.2.5.).

Table 2.1.2.5. Occipital lobe, size of.

Nature of Any Difference	Prepubertal		Postpubertal	
	Early Childhood	Adult	Adult	Adult
Males				
No signif. difference			NORTH AMERICA <i>United States</i> : DeCarli et al. 2005	
Females				

2.1.2.6. Visual Cortex, Size of

The visual cortex is the outermost layer of cells in the occipital lobe and is involved in processing visual information. Among rats, one study found males with a larger subportion of the visual cortex but no difference in another subportion. In humans, one study indicated that females had a larger subsection (Table 2.1.2.6).

Table 2.1.2.6. Visual cortex, size of.

Nature Any Difference	Prepubertal		Postpubertal	
	Early Childhood	Adult	Adult	Adult
Males larger		RODENT <i>Rat</i> : Seymoure & Juraska 1992* (at weaning, thickness in layer II-IV of the binocular subfield)		RODENT <i>Rat</i> : Reid & Juraska 1992 (more neurons in the binocular areas); Reid & Juraska 1995 (more neurons in the binocular areas)
No signif. difference		RODENT <i>Rat</i> : Seymoure & Juraska 1992* (at weaning, thickness of the monocular subfield)		
Females larger				NORTH AMERICA <i>United States</i> : Pietrini et al. 2000:1778 (young, in the binocular areas)

2.1.3. Size Differences in the Hemispheres and Connective Tissue

The neocortex is clearly identifiable as having left and right halves, called *hemispheres*. These hemispheres generally control the opposite side of the body, a phenomenon known as contralateral control. As shown in the tables below, various aspects of the two hemispheres have been examined with respect to sex differences.

2.1.3.1. Relative Size of the Hemispheres (Physical Brain Asymmetry)

Numerous studies have compared the two hemispheres in terms of their relative size. As shown in Table 2.1.3.1, nearly all of these investigations have concluded that, among humans, males have a greater disparity in the size of their hemispheres than do females. The most common difference has been that males have a larger right than left hemisphere, whereas in females the hemispheres are more evenly proportioned in overall size. In the case of rodents, the nature of any gender difference appears to be difficult to characterize and may depend on specific regions of the neocortex.

Table 2.1.3.1. Relative size of the hemispheres (physical brain asymmetry).

Nature of Any Difference	Prepubertal		Postpubertal	
	Early Childhood	Adult	Adult	Multiple Age Categories
Greater/larger in males		NORTH AMERICA <i>United States</i> : Bear et al. 1986; Kulynych et al. 1994; Reite et al. 1995; Gur et al. 2000 RODENT <i>Rat</i> : MC Diamond 1987 (in the occipital region)		NORTH AMERICA <i>United States</i> : Wade 1975; Ray et al. 1976; Trotman & Hammond 1979; A Glass et al. 1984; Rippon 1990; Shaywitz et al. 1995; Kansaku et al. 2000
No signif. difference		EUROPE <i>France</i> : Robichon et al. 1999 (neuroimaging of the planum tempore area)		
Greater/larger in females				

2.1.3.2. Right Hemisphere, Size of

As shown in Table 2.1.3.2, studies have reached somewhat conflicting results regarding the possibility of a sex difference in the size of the right hemisphere of the neocortex, although most studies of humans and rodents suggest that it is larger in males than in females.

Table 2.1.3.2. Right hemisphere, size of.

Nature of Any Difference	Prepubertal			Postpubertal	Multiple Age Categories
	Infant	Childhood	Adult		
Greater/larger in males	NORTH AMERICA <i>United States</i> : Shucard et al. 1984 (neonate); de Lacoste et al. 1991 (fetal development); Gratton et al. 1992 (neonate)	RODENT Rat : MC Diamond et al. 1981 (larger right than left)	RODENT Rat : MC Diamond et al. 1981 (larger right than left in areas 17 & 39); MC Diamond 1988:21 (larger right than left)	NORTH AMERICA <i>United States</i> : MC Diamond et al. 1981; G Murphy 1984 OCEANIA <i>Australia</i> : Yucel et al. 2001	
No signif. difference					
Greater/larger in females	RODENT Rat : Tobet et al. 1993 (postnatal day 20, barrel cortex)		NORTH AMERICA <i>United States</i> : Rademacher 2001 (postmortem)		

2.1.3.3. Left Hemisphere, Size of

One study of rats reached the conclusion that the left hemisphere of males was larger than was that of females (Table 2.1.3.3).

Table 2.1.3.3. Left hemisphere, size of.

Nature of Any Difference	Prepubertal				
	Infant				
Greater/larger in males	RODENT Rat : Tobet et al. 1993 (postnatal day 20, barrel cortex)				
No signif. Difference					
Greater/larger in females					

2.1.3.4. Corpus Callosum, Size of

The corpus callosum is the tissue of the brain connecting the two hemispheres, with portions also connecting the neocortex as a whole to subcortical regions of the brain. Considerable research has investigated possible gender differences in the size of the corpus callosum and its various subdivisions. As shown in Table 2.1.3.4, in humans, most but not all studies have found the corpus callosum to be larger in females than in males. Findings for other species have been mixed.

Table 2.1.3.4. Corpus callosum, size of.

Nature of Any Difference	Prepubertal			Postpubertal	Multiple Age Categories
	Infant	Childhood	Adult		
Larger in males			EUROPE <i>Germany</i> : R Westerhausen et al. 2004 (overall volume) RODENT Rat : Berrebi et al. 1988 (overall corpus callosum); Zimmerberg & Mickus 1990* (overall corpus callosum); Ojima et al. 1996 (midsagittal area)		
No signif. difference	RODENT Rat : Zimmerberg & Scalzi 1989* (postnatal day 3, midline sagittal areas of the anterior commissure)		NORTH AMERICA <i>United States</i> : RM Bishop & Wahlsten 1997 (posterior portion) RODENT Mouse : Zimmerberg & Mickus 1990* (midline sagittal area of the anterior commissure); Ojima et al. 1996 (anterior commissure); Manhaes et al. 2002 (length, BALB/cCF strain); <i>Rat</i> : Mack et al. 1995* (genu region in Purdue-Wistar rats; diameter of axon)	NORTH AMERICA <i>United States</i> : Demeter et al. 1988 (anterior commissure); Highley et al. 1999 (anterior commissure); Lasco et al. 2002 (anterior commissure)	
Larger in females			NORTH AMERICA <i>Canada</i> : Witelson 1989 (college, overall size); N Driesen & Raz 1995 (overall size); <i>United States</i> : De Lacoste-Utamsing & Holloway 1982 (posterior portion); LS Allen & Gorski 1991 (anterior commissure) RODENT Rat : Mack et al. 1995* (genu region in Purdue-Wistar rats; diameter of axon)	NORTH AMERICA <i>United States</i> : DeLacoste-Utamsing & Holloway 1982 (bulbous splenium); S Clark et al. 1989; LS Allen & Gorski 1992 (anterior commissure); M Hines et al. 1992; Steinmatz et al. 1992; JM Clarke & Zaidel 1994; Shaywitz et al. 1995; Salat et al. 1997 (bulbous splenium); Davatzikos & Resnick 1998 (bulbous splenium)	

2.1.3.5. Temporal Lobe, Size of

The temporal lobes are part of each hemisphere, located on each side of the brain between the frontal lobes and the occipital lobes. It is unclear the extent to which the size of the temporal lobes is sexually dimorphic (Table 2.1.3.5).

Table 2.1.3.5. Temporal lobe, size of.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					NORTH AMERICA <i>United States</i> : Bryant et al. 1999
No signif. difference					NORTH AMERICA <i>United States</i> : DeCarli et al. 2005
Larger in females					

2.1.3.6. Broca's Area, Size of

On the left frontal lobe is a region of the brain that is instrumental in the production of speech for the vast majority of humans. The two studies that compared the sexes with respect to the size of this region, called Broca's area, concluded that it is significantly larger in females than in males (Table 2.1.3.6).

Table 2.1.3.6. Broca's area, size of.

Nature of Any Difference					Multiple Age Categories
Larger in males					
No signif. Difference					
Larger in females					EUROPE <i>France</i> : Robichon et al. 1999 (neuroimaging) NORTH AMERICA <i>United States</i> : Harasy et al. 1997

2.1.3.7. Wernicke's Area, Size of

Wernicke's area is located in the posterior portion of the neocortex's left hemisphere. In nearly all humans, it serves to interpret linguistic communication. One study concluded that Wernicke's area is larger on average in females than in males (Table 2.1.3.7).

Table 2.1.3.7. Wernicke's area, size of.

Nature of Any Difference					Multiple Age Categories
Larger in males					
No signif. difference					
Larger in females					NORTH AMERICA <i>United States</i> : Harasy et al. 1997

2.1.4. Subcortical Brain Regions (Except the Hypothalamus)

All parts of the brain other than the neocortex are collectively known as the *subcortex*. The findings from studies of sex differences in these brain regions except for the hypothalamus are presented in the following tables.

2.1.4.1. Subcortical Asymmetry in General or for a Minor Region of the Subcortex

Research findings concerning sex differences in one small subcortex brain region are reported in Table 2.1.4.1. They indicate that among rats, the suprachiasmatic nucleus is more asymmetrical in males than females.

Table 2.1.4.1. Subcortical asymmetry in general or for a minor region of the subcortex.

Nature of Any Difference					Postpubertal
					Adult
Greater asymmetry in males					RODENT <i>Rat</i> : Guldner 1982 (asymmetric synapses in the SCN)
No signif. Difference					
Greater asymmetry in females					

2.1.4.2. Amygdala, Size of

The amygdala is part of the limbic system or emotion-regulating portion of the mammalian subcortex. A few studies have investigated male-female differences in the size of the amygdala, or parts thereof. Table 2.1.4.2 indicates that in rodents, the amygdala appears to be larger than in males than in females. Regarding humans, studies have been split between finding no significant gender differences or concluding that at least portions of the amygdala are larger in males than in females.

Table 2.1.4.2. Amygdala, size of.

Nature of Any Difference	Prepubertal		Postpubertal	
	Childhood		Adult	
Larger in males	NORTH AMERICA <i>United States</i> : Caviness et al. 1996		NORTH AMERICA <i>United States</i> : Goldstein et al. 2001 RODENT <i>Mouse</i> : Koshibu et al. 2004 (medial region, 3-D MRI, C57Bl/6J strain); <i>Rat</i> : Mizukami et al. 1983; Hines et al. 1992 (posterodorsal region)	
No signif. difference	NORTH AMERICA <i>United States</i> : Giedd et al. 1997		NORTH AMERICA <i>United States</i> : Murphy GM 1986 (medial region); Bryant et al. 1999 (amygdala/hippocampal complex); Gur et al. 2002	
Larger in females				

2.1.4.3. Basal Ganglia, Size of

The basal ganglia are a cluster of nerve cells located at the base of the brain, comprising the putamen, caudate, globus pallidus, and substantia nigra. These nerve cells play an important role in regulating motor control. The caudate is also part of the limbic system. As shown in Table 2.1.4.3, a single study concluded that the basal ganglia of males are larger than those of females.

Table 2.1.4.3. Basal ganglia, size of.

Nature of Any Difference	Prepubertal			
	Childhood			
Larger in males				NORTH AMERICA <i>United States</i> : JN Giedd et al. 1997 (globus pallidus region, brain imaging technique)
No signif. difference				
Larger in females				

2.1.4.4. Bed Nucleus of the Stria Terminalis, Size of

The bed nucleus of the stria terminalis (or bed nucleus terminalis) is a small portion of the hypothalamus that is found in several species of mammals including humans, and is connected to the amygdala by way of the stria terminalis. Research has consistently shown that this segment of the hypothalamus is larger in males than in females both in humans and in rodents (Table 2.1.4.4).

Table 2.1.4.4. Bed nucleus of the stria terminalis, size of.

Nature of Any Difference	Prepubertal		Postpubertal	
	Infant		Adult	
Larger in males	NORTH AMERICA <i>United States</i> : del Abril et al. 1987		EUROPE <i>Netherlands</i> : Zhou et al. 1995 (measured by vasoactive intestinal peptide immunoreactivity); Zhou et al. 1997; Chung et al. 2002; Swaab 2004 NORTH AMERICA <i>United States</i> : LS Allen et al. 1989; LS Allen & Gorski 1990 RODENT <i>Guinea Pig</i> : M Hines et al. 1985; <i>Rat</i> : del Abril et al. 1987 (medial posterior regions, not lateral, ventral, or intermediate divisions); M Hines et al. 1992 (encapsulated region)	
No signif. difference				
Larger in females				

2.1.4.5. Brainstem, Size of

The brainstem is the lower portion of the brain with connection to the spinal cord. The one available study on sex differences in the size of the brainstem concluded that once adjustments are made for sex differences in brain size, no significant sex difference in the brainstem size exists (Table 2.1.4.5).

Table 2.1.4.5. Brainstem, size of.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					
No signif. difference					NORTH AMERICA <i>United States</i> : Filipek et al.1994:352 (relative to overall brain size)
Larger in females					

2.1.4.6. Pyramidal Cell Field of the Hippocampus, Volume of

The pyramidal cell field is part of the hippocampus and is itself subdivisible into different sectors. Studies of sex differences in the size of this cell field have all concluded that it is larger in males than in females, at least among rats (Table 2.1.4.6).

Table 2.1.4.6. Pyramidal cell field of the hippocampus, volume of.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					RODENT <i>Rat</i> : Juroska et al. 1989 (CA3); Madeira et al. 1992 (CA1); Isgor & Sengelaub 1996 (CA3); Isgor & Sengelaub 1998:191 (CA1 & CA3)
No signif. difference					
Larger in females					

2.1.4.7. Caudate Nucleus, Size of

The caudate nucleus, also called the caudatum, is an elongated mass of grey matter located adjacent to the temporal lobes. According to two human studies, the caudate nucleus is larger in females than in males (Table 2.1.4.7).

Table 2.1.4.7. Caudate nucleus, size of.

Nature of Any Difference					Prepubertal
					Childhood
Larger in males					
No signif. difference					
Larger in females					NORTH AMERICA <i>United States</i> : JN Giedd et al. 1997 (brain-imaging study); Filipek et al. 1994 (12% larger)

2.1.4.8. Cerebellum, Size of

Among humans and other mammals, the cerebellum is found in the posterior portion of the brain, and is clearly distinguishable from the remainder of the brain by its structure and color. Among other functions, it is important in controlling movement. Studies among humans have concluded that on average the absolute size of the cerebellum of males is larger than that of females, although adjusting for overall brain size seems to eliminate the difference (Table 2.1.4.8).

Table 2.1.4.8. Cerebellum, size of.

Nature of Any Difference					Postpubertal	Multiple Age Categories
					Adult	
Larger in males					NORTH AMERICA <i>United States</i> : Nopoulos et al. 2000*; Raz et al. 2001; JS Allen et al. 2002	NORTH AMERICA <i>United States</i> : Henery & Mayhew 1989; Raz et al. 1998 (in the vermis & ventral pons of the cerebellum)
No signif. difference					NORTH AMERICA <i>United States</i> : Holloway et al. 1993 (corrected for brain size); Filipek et al.1994:352 (overall brain size controlled); Nopoulos et al. 2000* (adjusted for overall brain size differences) FISH <i>Atlantic Stingray</i> : Puzdrowski & Leonard 1992 (caudal part of the anterior cerebellum)	
Larger in females						

2.1.4.9. Hippocampus, Size and Composition of

The hippocampus is vital to many long-term and short-term memory functions. Among humans, most studies have concluded that the hippocampus in females is larger than that of males. However, for various species of rodents (except for the mouse), studies have usually found the opposite sex difference (Table 2.1.4.9). It is likely that sex differences in the hippocampus will be species-dependent and closely related to the natural ecology of the species.

Table 2.1.4.9. Hippocampus, size and composition of.

Nature of Any Difference	Prepubertal		Postpubertal		Multiple Age Categories
	Childhood	Adolescent	Adult		
Larger in males	RODENT Guinea Pig: Bartesaghi et al. 2003; Severi et al. 2005; Rats: MC Diamond et al. 1982*; Juraska 1990; Roof 1993a	RODENT Rats: MC Diamond et al. 1982*	RODENT Gray Squirrel: Lavenen et al. 2000; Meadow Vole: LF Jacobs et al. 1990*; Mouse: Wimer & Wimer 1985; Wimer et al. 1988; Wimer & Wimer 1989; Tabibnia et al. 1999; Rats: MC Diamond et al. 1982*; MC Diamond et al. 1983; MD Madeira et al. 1988; Juraska et al. 1985; Juraska et al. 1989; E Gould et al. 1990; Madeira et al. 1991; Madeira et al. 1992; Roof & Havens 1992; Madeira & Barbosa 1993; Perifilieva et al. 2001 (Sprague-Dawley & spontaneously hypertensive rats, number of granule cells in the dentate gyrus)		
No signif. difference	NORTH AMERICA United States: JN Giedd et al. 1997 (volume)		NORTH AMERICA United States: Bryant et al. 1999 (amygdalar/hippocampal complex) BIRD Bay-winged Cowbird: Reboreda et al. 1996*; Cowbird: Clayton et al. 1997; Screaming Cowbird: Reboreda et al. 1996* RODENT Mouse: Koshibu et al. 2004 (3-D MRI; C57Bl/6J strain); Pine Vole: LF Jacobs et al. 1990*; Rat: Madeira et al. 1988 (DG-GCL volume); Ignor & Sengelaub 1999 (DG-GCL volume); Tanapat et al. 1999 (young)		
Larger in females	NORTH AMERICA United States: Giedd et al. 1996*	NORTH AMERICA United States: Giedd et al. 1996*	NORTH AMERICA United States: Filipek et al. 1994 (young); Caviness et al. 1996; DGM Murphy et al. 1996; Goldstein et al. 2001 BIRD Shiny Cowbird: Reboreda et al. 1996*		NORTH AMERICA United States: JM Goldstein et al. 2001

2.1.4.10. Locus Coeruleus, Size of

The locus coeruleus is a small portion of the brain stem containing high concentrations of norepinephrine neurons and is thought to play an important role in anxiety and fear responses. In rats, the available research suggests that females have a wider locus coeruleus while the same structure for males tends to be longer, but no consistent overall size difference in the locus coeruleus has been documented (Table 2.1.4.10).

Table 2.1.4.10. Locus coeruleus, size of.

Nature of Any Difference	Prepubertal		Postpubertal	
	Childhood	Adolescent	Adult	
Larger in males			RODENT Rats: Babstock et al. 1997* (anterior-posterior length; dorsal ascending area to the hippocampus)	
No signif. difference			RODENT Rats: Babstock et al. 1997* (overall volume)	
Larger in females			RODENT Rats: Guillonon et al. 1988 (total volume & number of neurons); Segovia et al. 1991; Luque et al. 1992 (volume & somatic area in the anterior intermediate region); Babstock et al. 1997* (dorsal-lateral width); Kubo et al. 2003 (Wistar strain)	

2.1.4.11. Olfactory Bulb, Size of

As its name implies, the olfactory bulb is important for interpreting odors. In rats, two studies have suggested that it is larger in males than in females (Table 2.1.4.11).

Table 2.1.4.11. Olfactory bulb, size of.

Nature of Any Difference	Prepubertal		Postpubertal	
	Childhood	Adolescent	Adult	
Larger in males			RODENT Rat: Segovia et al. 1984 (volume); Valencia et al. 1986 (number of granule cells & number of mitral cells)	
No signif. difference				
Larger in females				

2.1.4.12. Spinal Cord (and Parts There of), Size of

Two studies – one of humans and the other of rats – have concluded that the volume of the spinal nucleus innervating the bulbocavernosus muscle is greater in males than in females (Table 2.1.4.12).

Table 2.1.4.12. Spinal cord (and parts thereof), size of.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					NORTH AMERICA <i>United States</i> : Forger & Breedlove 1986 (spinal nucleus of the bulbocavernosus) RODENT <i>Rat</i> : Breedlove & Arnold 1980 (spinal nucleus of the bulbocavernosus)
No signif. difference					
Larger in females					

2.1.4.13. Striatum, Size of

The striatum is a large division of the forebrain. It is comprised of the caudate nucleus and the putamen and is richly innervated by dopamine pathways. Functionally, it plays a central role in movement. Research in humans is mixed regarding any sex difference, and in the mouse one study revealed no significant difference (Table 2.1.4.13).

Table 2.1.4.13. Striatum, size of.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					EUROPE <i>Austria</i> : Tauscher-Wisniewski et al. 2005 (volume of caudate using MRI)
No signif. difference					NORTH AMERICA <i>United States</i> : Bryant et al. 1999 (volume of caudate using MRI) EUROPE <i>Czech Republic</i> : Brabec et al. 2003 (volume of striatum, caudate-accumbens, putamen, and pallidum) RODENT <i>Mouse</i> : Koshibu et al., 2004 (3-D MRI, C57Bl/6J strain)
Larger in females					

2.1.4.14. Telencephalic Region, Size of

Nearly all studies of the telencephalic region (and its sub-regions) for several species of birds have concluded that this region is larger in males than in females (Table 2.1.4.14). In avian species, this large region of the brain is comprised of many smaller nuclei, including those that control song production (e.g., HVC, RA, and IMAN).

Table 2.1.4.14. Telencephalic region, size of.

Nature of Any Difference					Multiple Age Categories
	Larger in males				
No signif. difference					BIRDS <i>Zebra Finch</i> : DeVoogd & Nottebohm 1981* (dendritic length in HVC & IMAN)
Larger in females					

2.1.4.15. Septum, Size of

The septum is a region within the mammalian forebrain and is part of the limbic system. Its function is not well known, although it seems to play an important role in emotion-driven behavior, especially aggression. Studies of rodents have not reached consistent conclusions regarding the possibility of the septum being sexually dimorphic (Table 2.1.4.15).

Table 2.1.4.15. Septum, size of.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					
No signif. difference					RODENT <i>Mouse</i> : Schaevitz & Berger-Sweeney 2005 (C57BL/6J; volume of medial septum & number of cholinergic neurons in the medial septum)
Larger in females					RODENT <i>Rat</i> : Tsukahara et al. 2004 (volume)

2.1.4.16. Thalamus, Size of

The thalamus is a bundle of nerve cells resembling an egg in size and shape, and is centrally located in the brain. This part of the brain serves to process and then route incoming sensory stimuli to various higher regions of the brain. Table 2.1.4.16 shows that females have a larger thalamus than do males according to available evidence.

Table 2.1.4.16. Thalamus, size of.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					
No signif. difference					
Larger in females					EUROPE <i>France</i> : Morel 1948 (massa intermedia portion, more often detectible size); <i>Switzerland</i> : Rabl 1958 (massa intermedia portion, more often detectible size) NORTH AMERICA <i>United States</i> : Nopoulos 2001 (massa intermedia portion, more often detectible size)

2.1.5. The Hypothalamus

Because of the subcomponent complexity of the hypothalamus, the findings of sex differences in the size of this brain structure and its subcomponents are reviewed separately from the remainder of the subcortex.

2.1.5.1. Hypothalamus as a Whole, Size of

The hypothalamus helps to regulate body temperature and other forms of homeostasis as well as the release of numerous hormones. The multiple functions of the hypothalamus reflects the fact that it is a very complex neuronal structure. According to Table 2.1.5.1, the hypothalamus as a whole is slightly larger among males than among females (without making adjustments for overall sex differences in brain or body size).

Table 2.1.5.1. Hypothalamus as a whole, size of.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					EUROPE: <i>Netherlands</i> : Zhou et al. 2001 NORTH AMERICA <i>United States</i> : JM Goldstein et al. 2001
No signif. difference					
Larger in females					

2.1.5.2. Anterior Hypothalamic Nucleus, Size of

According to a few studies of nonhumans, the dorsal portion of the anterior hypothalamic nucleus is larger in males than in females (Table 2.1.5.2).

Table 2.1.5.2. Anterior hypothalamic nucleus, size of.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					AMPHIBIAN <i>Whiptail Lizard</i> : J Wade & Crews 1992 (number of neurons) PRIMATE (EXCEPT APE) <i>Japanese Macaque</i> : Vasey & Pfaus 2005 (dorsal portion); <i>Rhesus Macaque</i> : Byne 1998 (dorsal portion & the interstitial nuclei)
No signif. difference					
Larger in females					

2.1.5.3. Anterior Hypothalamic Preoptic Area (AH/POA), Size of

Across several species of mammals, including humans, males appear to have a larger anterior hypothalamic preoptic area than do females, at least regarding some regions of this intricate area (Table 2.1.5.3).

Table 2.1.5.3. Anterior hypothalamic preoptic area (AH/POA), size of.

Nature of Any Difference	Postpubertal			
	Adult			
Larger in males				EUROPE Netherlands: Swaab & Fliers 1985 (INAH-1 region) MUSTELID Ferret: Tobet et al. 1986 NORTH AMERICA United States: LS Allen 1989* (INAH-2 & INAH-3 region); Le Vay 1991* (INAH-3); Byne et al. 2000* (INAH-2 region); Byne et al. 2001* (INAH-3 region) PRIMATE (EXCEPT APE) Rhesus Macaque: Byne 1998 RODENT; Gerbil: Commins & Yahr 1985; Guinea Pig: M Hines et al. 1985; Rat: Gorski et al. 1980
No signif. difference				NORTH AMERICA United States: LS Allen et al. 1989* (INAH-1 & INAH-4 regions); Le Vay 1991* (INAH-1, INAH-2, & INAH-4 regions); Byne et al. 2000* (INAH-1, INAH-3 regions); Byne et al. 2001* (volume, neuronal number, neuronal size, neuronal density in INAH-1, INAH-2, INAH-4; neuronal size & density in INAH-3 region)
Larger in females				

2.1.5.4. Anteroventral Periventricular (AVPv), Size of

The anteroventral periventricular (AVPv) is a portion of the rodent hypothalamus. Several studies of rats have concluded that the AVPv is larger in the brains of females compared to the brains of males, although one study reached the opposite conclusion (Table 2.1.5.4).

Table 2.1.5.4. Anteroventral periventricular (AVPv), size of.

Nature of Any Difference	Postpubertal			Multiple Age Categories
	Adolescent	Adult		
Larger in males				RODENT Rat: Blies et al. 1982
No signif. difference				
Larger in females		RODENT Rat: Simerly et al. 1984; EC Davis et al. 1993	RODENT Rat: GJ Bloch & Gorski 1988 (young); Murakami & Arai 1989; Simerly 1998 (young); Sumida et al. 1993 (young); Ahmed et al. 1991	RODENT Rat: EC Davis et al. 1996

2.1.5.5. Medial Preoptic Area (Nucleus), Size of

Sex differences in the size of the medial preoptic area (MPA) has been determined in various species of rodents. Most of these comparisons have indicated that the MPA is larger in males.

Table 2.1.5.5. Median preoptic area (nucleus), size of.

Nature of Any Difference	Postpubertal			Multiple Age Categories
	Adolescent	Adult		
Larger in males		RODENT Mouse: Gubernick et al. 1993*	RODENT Guinea Pig: Hines et al. 1985	RODENT Rat: Gorski et al. 1978; Simerly et al. 1984; Chung et al. 2000
No signif. difference			RODENT Mouse: Gubernick et al. 1993* (young)	
Larger in females				

2.1.5.6. Paraventricular Nucleus, Size of

The paraventricular nucleus is located bilaterally along the third ventricle. It is comprised of two parts, a magnocellular division and a parvocellular division. The magnocellular division projects to the posterior pituitary and is involved in the physiological regulation of water retention. The parvocellular portion has strong projections to the median eminence, where it releases hormones that help regulate the anterior pituitary hormones involved in the stress response. There appears to be no sex differences in the size of the paraventricular nucleus (Table 2.1.5.6).

Table 2.1.5.6. Paraventricular nucleus, size of.

Nature of Any Difference	Postpubertal			
	Adult			
Larger in males				
No signif. difference				EUROPE Netherlands: Hofman et al. 1988 RODENT Rats: Chung et al. 2000 (volume)
Larger in females				

2.1.5.7. Sexually Dimorphic Nucleus of the Preoptic Area (SDN-POA), Size of

The sexually dimorphic nucleus of the preoptic area is located adjacent to the hypothalamus. For all species of mammals investigated (including humans). This brain structure has been repeatedly found to be considerably larger in males than in females (Table 2.1.5.7).

As an aside, a few studies have manipulated early hormonal factors by castrating male rats soon after birth (which largely halts testosterone production) and by injecting female rats neonatally with testosterone. In adulthood, this procedure resulted in an abnormal reduction of the SDN-POA in males and an increase in the size of this brain structure in females (Arnold & Gorski 1984; Gorski 1986).

Table 2.1.5.7. Sexually dimorphic nucleus of the preoptic area (SDN-POA), size of.

Nature of Any Difference	Prepubertal		Postpubertal		Multiple Age Categories
	Infant		Adolescent	Adult	
Larger in males	RODENT Rat: CD Jacobson et al. 1980 (increase in size of SDN-MPOA during 1 st 10 days after birth)		RODENT Rat: Dohler et al. 1982; Dohler et al. 1984; Rhees et al. 1990	MUSTELID Ferret: Tobet et al. 1986 NORTH AMERICA United States: LS Allen et al. 1989 PRIMATE (EXCEPT APE) Rhesus Macaque: Byne 1998 RODENT; Guinea Pig: M Hines et al. 1985; <i>Mouse:</i> Bleier et al. 1982; S Robinson et al. 1985; AE Brown et al. 1999 (in most strains); <i>Rat:</i> Raisman & Field 1971; Gorski et al. 1978; Gorski et al. 1980; AP Arnold & Gorski 1984; DK Anderson et al. 1985; Larriva-Sahd 1991; EC Davis et al. 1996 UNGULATE Domestic Sheep: Roselli et al. 2004	RODENT Gerbil: D Commins & Yahr 1984a; D Commins & Yahr 1984b; <i>Hamster:</i> Greenough et al. 1977
No signif. difference					
Larger in females					

2.1.5.8. Suprachiasmatic Nucleus, Size of

The suprachiasmatic nucleus (SCN) is a small cluster of neurons located bilaterally at the base of the third ventricle. The SCN is best known as the location of the endogenous circadian clock. Findings are not entirely consistent regarding any significant sex difference in the size of this nucleus (Table 2.1.5.8).

Table 2.1.5.8. Suprachiasmatic nucleus, size of.

Nature of Any Difference			Postpubertal	
				Adult
Larger in males				EUROPE Netherlands: Swaab et al. 1994; Zhou et al. 1995
No signif. difference				EUROPE Netherlands: Hofman et al. 1988 RODENT Guinea Pig: Hines et al. 1985
Larger in females				

2.1.5.9. Loss of Suprachiasmatic Nucleus

The suprachiasmatic nucleus tends to diminish in size with age. One study of rats concluded that this deterioration was more pronounced in males than in females (Table 2.1.5.9).

Table 2.1.5.9. Loss of suprachiasmatic nucleus.

Nature of Any Difference			Postpubertal	
				Adult
Larger in males				RODENT Rat: Tsukahara et al. 2005 (faster rate & higher numbers)
No signif. difference				
Larger in females				

2.1.5.10. Ventromedial Hypothalamus, Size of

Two studies of the ventromedial hypothalamus reached contradictory conclusions regarding the possibility of an average sex difference in the size of this hypothalamic subcomponent, although the studies involved very different species (Table 2.1.5.10).

Table 2.1.5.10. Ventromedial hypothalamus, size of.

Nature of Any Difference			Postpubertal	
				Adult
Larger in males				RODENT Rats: Chung et al. 2000 (volume)
No signif. difference				
Larger in females				AMPHIBIAN Whiptail Lizards: D Crews et al. 1990; J Wade & Crews 1992 (number of neurons)

2.1.6. Age-Related Neuronal Transformations

Studies of the time needed for the brain, or parts thereof, to develop into a fully adult form are reviewed in the following tables.

2.1.6.1. Overall Brain Development Rate

The speed with which the brain assumes the physical or functional properties found in adult animals is referred to as *brain development*. Table 2.1.6.1 suggests that, at least among humans, female brains undergo more rapid development than do male brains.

Table 2.1.6.1. Overall brain development rate.

Nature of Any Difference	Prepubertal		Postpubertal	
	Childhood		Adolescent	
More rapid in males				
No signif. difference				
More rapid in females		EUROPE <i>England</i> : DC Taylor 1969		NORTH AMERICA <i>United States</i> : Epstein 1978:376; Hudspeth & Pribram 1990

2.1.6.2. Apoptosis (Nerve Cell Death/Neuronal Loss With Age/Neuronal Pruning)

In all animals, many more neurons are produced early in life than are present in the brains of adults. Thus, substantial cell death or pruning occurs with age and is known as *apoptosis*. A few studies have documented apoptosis occurring very early in life, but most studies measure it throughout development. Apoptosis has been shown to be greater in females than in males for several regions in the brains of rats and other rodents. In other brain regions, and for other species, no significant gender differences in apoptosis have been found (Table 2.1.6.2).

Table 2.1.6.2. Apoptosis (nerve cell death/neuronal loss with age/neuronal pruning).

Nature of Any Difference	Prepubertal		Postpubertal		Multiple Age Categories
	Infant		Adult		
More in males				NORTH AMERICA <i>United States</i> : Coffey 1998; Gur et al. 2002b	RODENT <i>Rat</i> : Tsukahara et al. 2004* (intermediate part of the later septum on postnatal day 16)
No signif. difference					BIRD <i>Zebra Finch</i> : Burek et al. 1997 (in the vocal control center) RODENT <i>Rat</i> : Davis et al. 1996 (in the lateral preoptic area); Chung et al. 2000 (in the lateral division of the bed nucleus of the stria terminalis or in the ventromedial hypothalamus & paraventricular nucleus); Tsukahara et al. 2004* (Dorsal and ventral parts of the lateral septum up to postnatal day 16 and intermediate parts on days 6, 8, and 11) MUSTELID <i>Ferret</i> : Park et al. 1998 (in the nucleus of the preoptic area & the anterior hypothalamus & the ventral preoptic area & the anterior hypothalamus)
More in females		RODENT <i>Rat</i> : Nordeen et al. 1985 (in the spinal nucleus of the bulbocavernosus); Beaston-Wimmer & Smolen 1991 (postnatal days 1-14, in the superior cervical ganglion); Davis et al. 1996 (in the central division of the medial preoptic nucleus between postnatal days 7-10)			RODENT <i>Gerbil</i> : Holman et al. 1996 (in the sexually dimorphic area pars compacta); <i>Rat</i> : Chung et al. 2000 (in the principal nucleus of the bed nucleus of the stria terminalis & in the medial preoptic nucleus); Nunez et al. 2001 (in the posterior cortex)

2.1.6.3. Timing of Apoptosis

One study of rats indicated that in at least one brain region, the peak in cell death came earlier in infancy for males than for females (Table 2.1.6.3).

Table 2.1.6.3. Timing of apoptosis.

Nature of Any Difference	Prepubertal			
	Infant			
Earlier for males	RODENT <i>Rat</i> : Nunez et al. 2001 (in the posterior cortex destined to become the visual cortex)			
No signif. difference				
Earlier for females				

2.1.6.4. Neocortical Brain Development Rate

The neocortex (or cerebrum) is the portion of the mammalian brain that in humans is responsible for most “higher thought” (such as making sense out of reading this book). One study found that this portion of the human brain developed more rapidly in females than in males at least during childhood (Table 2.1.6.4).

Table 2.1.6.4. Neocortical brain development rate.

Nature of Any Difference	Prepubertal			
	Childhood			
More rapid in males				
No signif. difference				
More rapid in females			EUROPE <i>England</i> : DC Taylor 1969* (speech areas of the left hemisphere)	

2.1.6.5. Decrease in Brain Volume With Age

Brain cell numbers decrease with age. As a result, the volume of the brain decreases (with the exception of the cerebral spinal fluid which increases). Studies undertaken to determine if any sex differences exist in this regard have concluded that the rate of the total brain volume lost is greater in males than in females (Table 2.1.6.5).

Table 2.1.6.5. Decrease in brain volume with age.

Nature of Any Difference	Postpubertal			
	Adult			
Greater decline in males			ASIA <i>Japan</i> : Xu et al. 2000 NORTH AMERICA <i>Canada</i> : Witelson 1991; <i>United States</i> : CE Coffey 1998; JS Meyer 1999; Gur et al. 2001; Gur et al. 2002	
No signif. difference				
Greater decline in females				

2.1.6.6. Decrease in Gray Matter With Age

Studies of the loss of gray matter with age have indicated that female losses surpass those of males (Table 2.1.6.6).

Table 2.1.6.6. Decrease in gray matter with age.

Nature of Any Difference	Postpubertal			
	Adult			
Greater decline in males				
No signif. difference				
Greater decline in females			NORTH AMERICA <i>United States</i> : Gur et al. 1999 (gray matter, proportion of total); Hommer et al. 2001 (alcoholics, amount of gray matter)	

2.1.6.7. Decrease in Cerebrospinal Fluid With Age

One study indicated that males on average lose a greater proportion of cerebrospinal fluid (CSF) as they age than do females (Table 2.1.6.7).

Table 2.1.6.7. Decrease in cerebrospinal fluid with age.

Nature of Any Difference	Postpubertal			
	Adult			
Males lose more				NORTH AMERICA <i>United States</i> : Gur et al. 1999 (proportion of total)
No signif. difference				
Females lose more				

2.2

CELLS IN THE BRAIN AND SPINAL CORD

Two types of nerve cells are recognized: neurons and glia cells. There are many more glia cells than nerve cells. Traditionally, glia have been thought to support metabolic functions for nerve cells. For example, some glia manufacture myelin. As revealed in the following tables, sex differences occur in nerve cell numbers, size, and structural components. Most research on nerve cells has focused on neurons rather than on glia cells.

2.2.1. Neuronal Numbers

Research findings pertaining to the number of neurons are presented in two tables, one pertaining to neocortical portions of the brain and the other having to do with subcortical regions.

2.2.1.1. Neurons in Regions of the Neocortex, Numbers of

Sexual dimorphism in neuron numbers has been indicated in various studies, although the nature of the sex difference varies depending upon the region of the brain under consideration. Among humans, the right hemisphere of males appears to contain a greater total number of neurons than does the right hemisphere of females. On the other hand, two studies indicate that females have a greater number of neurons in posterior regions of the corpus callosum than do males. In one species of song birds, the brain region controlling song production contains more neurons in males than in females.

Table 2.2.1.1. Neurons in regions of the neocortex, numbers of.

Nature of Any Difference	Postpubertal			
	Adult			
More in males				NORTH AMERICA <i>United States</i> : DeCourten-Myer 1988 (in the right hemisphere) BIRD <i>Zebra Finch</i> : Burek et al. 1993 (in the brain's vocalization control centers)
No signif. difference				NORTH AMERICA <i>Canada</i> : Witelson et al. 1995* (among right handers, layers III, V, and VI of the TA1 region of the right hemisphere); <i>United States</i> : Rabinowicz et al. 1999 (in general) RODENT <i>Rat</i> : Kopcik et al. 1992 (projecting within the visual via the corpus callosum)
More in females				NORTH AMERICA <i>Canada</i> : Witelson 1989 (in the isthmus of the corpus callosum); Witelson et al. 1995* (among right handers, layers II and IV of the TA1 region of the right hemisphere); <i>United States</i> : S Clarke et al. 1989 (in the posterior part of the corpus callosum)

2.2.1.2. Neurons in Regions of the Subcortex in General, Numbers of

According to two studies of adults – one of humans and the other of rats – neurons in at least a few subcortical regions have been found to be greater in number for males than for females. However, a study of neonates found no sex difference in another subcortical region (Table 2.2.1.2).

Table 2.2.1.2. Neurons in regions of the subcortex in general, numbers of.

Nature of Any Difference	Prepubertal		Postpubertal	
	Infant		Adult	
Males have more				EUROPE <i>Netherlands</i> : Krvijver et al. 2000 (somatostatin neurons in the bed nucleus of the stria terminalis) RODENT <i>Rat</i> : Dyer et al. 1976 (in the POA projection to the medial basal hypothalamus)
No signif. difference				RODENT <i>Rat</i> : Beaston-Wimmer & Smolen 1991 (postnatal day 1, in the superior cervical ganglion mRNA)
Females have more				

2.2.1.3. Neuron Size

One study of the size of neurons in the amygdala of monkeys found the neurons to be larger in males than in females, while the other study on this topic concluded the opposite, at least with respect to neurons in the left hemisphere of the neocortex [p (Table 2.2.1.3).

Table 2.2.1.3. Neuron size.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					PRIMATE (EXCEPT APE) <i>Rhesus Macaque</i> : Bubenik & Brown 1973
No signif. difference					
Larger in females					NORTH AMERICA <i>United States</i> : Rabinowicz et al. 2002 (in the left hemisphere)

2.2.1.4. Neuronal Projections

One study of fleshflies concluded that only males have neurons that project specifically to the flight muscles (Table 2.2.1.4). This coincides with the fact that in this species only males engage in high-speed chases.

Table 2.2.1.4. Neuronal projections.

Nature of Any Difference					Postpubertal
					Adult
Males have more					INSECTS <i>Fleshflies</i> : C Gilbert & Strausfeld 1991 (in the lobula)
No signif. difference					
Females have more					

2.2.1.5. Bed Nucleus of the Stria Terminalis

The bed nucleus of the stria terminalis basically connects the amygdala with the hypothalamus, and appears to help mediate emotional responses to incoming stimuli. The available evidence is not entirely consistent regarding possible sexual dimorphism in this component of the brain (Table 2.2.1.5).

Table 2.2.1.5. Bed nucleus of the stria terminalis.

Nature of Any Difference					Postpubertal
					Adult
More among males					RODENT <i>Rat</i> : (projections to anteroventral periventricular nucleus of the hypothalamus and premamillary nucleus, PHA-L tract tracing, Sprague Dawley)
No signif. difference					RODENT <i>Rat</i> : (projections to ventromedial nucleus of the hypothalamus, PHA-L tract tracing, Sprague Dawley)
More among females					

2.2.1.6. Neurogenesis

Neurogenesis is the process by which neurons are born. During fetal development, neurogenesis occurs along the ventricles. The neurons then migrate to the appropriate position. At least in rodents, neurogenesis appears to generally either be greater in males than females or there is no significant difference (Table 2.2.1.6). This process may underlie the general dimorphism in brain size.

Table 2.2.1.6. Neurogenesis.

Nature of Any Difference					Multiple Age Categories
	Males have more				
No signif. difference					RODENT <i>Guinea pig</i> : Byne et al. 1987 (number of neurons born & duration of neurogenesis in several hypothalamic nuclei); <i>Mouse</i> : Schaevitz & Berger-Sweeney 2005* (C57BL/6J; duration of neurogenesis of cholinergic neurons in the medial septum)
Females have more					

2.2.2. Nerve and Glia Cell Numbers (Density)

Two types of nerve cells are found throughout nearly all animal brains: glia and neurons. Variations in the density of these cells are covered in the following section.

2.2.2.1. Glia Cells

Originally named after the German word for *glue*, the function of glia cells in the brain remains largely unresolved, although these cells seem to have a variety of enhancing and support roles to play relative to the brain's more numerous neurons (Garcia-Sagura & McCarthy 2003). According to Table 2.2.2.1, any gender difference in the prevalence of glia cells may vary by species.

Table 2.2.2.1. Glia cells.

Nature of Any Difference	Postpubertal	
	Infant	Adult
More in males		RODENT Rat: Chowen et al. 1995 (number of GFAP immunoreactivity in the median eminence & arcuate nucleus)
No signif. difference		PRIMATE (EXCEPT APE) Tree Shrew: Michaels et al. 2001
More in females		

2.2.2.2. Ratio of Neurons to Glia Cells

One study determined that in at least one region of the neocortex, male rats had a higher neuron-to-glia ratio than did females (Table 2.2.2.2).

Table 2.2.2.2. Ratio of neurons to glia cells.

Nature of Any Difference	Postpubertal	
	Infant	Adult
Higher in males		RODENT Rat: McShane et al. 1988 (in the neocortex area 39)
No signif. difference		
Higher in females		

2.2.2.3. Neuronal Density

Neuronal density pertains to the number of nerve cells located within a cubic centimeter of brain tissue. According to Table 2.2.2.3, males have greater neuronal density in the neocortex than do females.

Table 2.2.2.3. Neuronal density.

Nature of Any Difference	Prepubertal		Postpubertal	
	Infant	Adolescent	Adolescent	Adult
Greater in males			NORTH AMERICA United States: Pakkenberg & Gundersen 1997* (in the neocortex); Rabinowicz et al. 1999 (in the neocortex)	NORTH AMERICA United States: Pakkenberg & Gundersen 1997* (in the neocortex)
No signif. difference	RODENT Rat: Nunez et al. 2001 (postnatal days 2-35, in the posterior cortex)			
Greater in females				

2.2.2.4. Neuronal Ganglia and Preganglia

Ganglia and preganglia are structures associated with the autonomic nervous system. Both are located outside the central nervous system and contain a synapse. All available studies (none of which involve humans) indicate that males have more cells in these neuronal structures than do females (Table 2.2.2.4).

Table 2.2.2.4. Neuronal ganglia and preganglia.

Nature of Any Difference					Postpubertal
					Adult
More in males					FELINE <i>Cat</i> : R Baron et al. 1985 RODENT <i>Guinea Pig</i> : McLochlan 1985; <i>Mouse</i> : Suzuki & Arai 1986; <i>Rat</i> : Dail et al. 1975 (neuronal ganglia); Nadelhaft & Booth 1984; Papka & Trauring 1985 (neuronal ganglia); D Greenwood et al. 1985; Nadelhaft & McKenna 1987; Papka et al. 1987 (neuronal ganglia); BW Newton & Hamill 1988; Keast & Groat 1989 (neuronal ganglia); Pacheco et al. 1989 (neuronal ganglia); BW Newton et al. 1990; BW Newton 1992
No signif. difference					
More in females					

2.2.3. Specialized Types of Neurons

Some neurons perform special functions associated with the chemical substance they release in order to communicate with other cells in the body (either a transmitter substance or a hormone).

2.2.3.1. Corticotropin-Releasing Hormone Containing Neurons, Numbers of

Neurons containing corticotropin-releasing hormone have been found to be greater in number in at least one subcortical region of the rat brain of females relative to the same region in male rats (Table 2.2.3.1).

Table 2.2.3.1. Corticotropin-releasing hormone containing neurons, numbers of.

Nature of Any Difference					Postpubertal
					Adult
More in males					
No signif. difference					
More in females					RODENT <i>Rat</i> : Funabashi 2003 (Wister, in the preoptic area of the bed nucleus & the stria terminalis)

2.2.3.2. Dopaminergic Neurons, Number of

According to one study of rats, males have more neurons that utilize the neurotransmitter dopamine than do females in at least one subcortical region (Table 2.2.3.2).

Table 2.2.3.2. Dopaminergic neurons, number of.

Nature of Any Difference					Postpubertal
					Adult
More in males					RODENT <i>Rat</i> : Simerly et al. 1985 (in the anteroventral periventricular nucleus)
No signif. difference					
More in females					

2.2.3.3. Dopaminergic Neurons, Size of

One study of rats compared the size of dopaminergic nerve cells and concluded that those in males were larger than those in females (Table 2.2.3.3).

Table 2.2.3.3. Dopaminergic neurons, size of.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					RODENT <i>Rat</i> : Reisert & Pilgrim 1991 (30% larger)
No signif. difference					
Larger in females					

2.2.3.4. Motoneurons, Number of

Studies among multiple species of mammals (including humans) have found greater numbers of motoneurons (or motor neurons) in the spinal cords of males relative to females (Table 2.2.3.4). For non-mammals, however, sex differences in motoneurons have not been detected.

Table 2.2.3.4. Motoneurons, number of.

Nature of Any Difference					Postpubertal
					Adult
More in males					NORTH AMERICA <i>United States</i> : Forger & Breedlove 1986 (in Onuf's nucleus of the spinal cord) CANINE <i>Dog</i> : Forger & Breedlove 1986 (in Onuf's nucleus of the spinal cord); <i>Hyena</i> : Forger et al. 1996 (in the Onuf's nucleus) RODENT <i>Rat</i> : CL Jordan et al. 1982 (in the dorsolateral motor nucleus of the spinal cord); Nordeen et al. 1985 (in the spinal nucleus of the bulbocavernosus)
No signif. difference					AMPHEBIAN <i>Green Anole</i> : O'Bryant & Wade 1999 (in the vagal portion of the nucleus ambiguus and ventral motor nucleus of facial nerves) BIRD <i>Zebra Finch</i> : J Wade & Buhlman 2000 (number and size of neurons in vocal organ)
More in females					

2.2.3.5. Muscle Innervation

According to one study of rats, males had much greater muscle innervation than did females (Table 2.2.3.5).

Table 2.2.3.5. Muscle innervation.

Nature of Any Difference					Postpubertal
					Adult
More in males					RODENT <i>Rat</i> : CL Jordan et al. 1982 (ischioavernosus muscle innervation by dorsolateral motor nucleus neurons)
No signif. difference					
More in females					

2.2.3.6. Nucleus Ambiguus

As one of the cranial nerves, the nucleus ambiguus plays a central role in swallowing. As shown in Table 2.2.3.6, males appear to have larger and more complexly developed nerves in the nucleus ambiguus, at least among one amphibian species.

Table 2.2.3.6. Nucleus ambiguus.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					AMPHEBIAN <i>Green Anole</i> : O'Bryant & Wade 1999 (soma size in area X & nerve cross section for nerves)
No signif. difference					
Larger in females					

2.2.3.7. Somatostatin Neurons, Number of

Somatostatin is a hormone produced by various cells of the body, including certain nerve cells within the hypothalamus. One study found greater numbers of somatostatin producing neurons in the brains of males than in those of females (Table 2.2.3.7).

Table 2.2.3.7. Somatostatin neurons, number of.

Nature of Any Difference					Postpubertal
					Adult
Males have more					EUROPE <i>Netherlands</i> : Kruiver et al. 2000 (in the bed nucleus of the stria terminalis)
No signif. difference					
Females have more					

2.2.4. Neuronal Component Structures

The structures of various subcomponents of neurons have been investigated by researchers with respect to sex differences. Results from these studies are summarized below.

2.2.4.1. Axons (Neurites), Number of

Research findings have not been consistent with regard to any gender differences in the numbers of axons in various areas of the brain (Table 2.2.4.1).

Table 2.2.4.1. Axons (neurites), number of.

Nature of Any Difference					Postpubertal	
					Adolescent	Adult
More in males						RODENT Rat: Kim & Juraska 1997* (young, in the splenium of the corpus callosum)
No signif. difference					RODENT Rat: Kim & Juraska 1997* (in the splenium of the corpus callosum)	
More in females					EUROPE Switzerland: Rabinowicz et al. 2002 RODENT Rat: Loy & Milner 1980 (axonal sprouting in the hippocampus)	RODENT Rat: Juraska & Kopcik 1988 (in the splenium of the corpus callosum); Kin & Juraska 1993 (in the splenium of the corpus callosum)

2.2.4.2. Axon Withdrawal, Age of Onset

One study of the age at which axon withdrawal begins found it to be earlier in males than in females, at least in a portion of the rat corpus callosum (Table 2.2.4.2).

Table 2.2.4.2. Axon withdrawal, age of onset.

Nature of Any Difference					Multiple Age Categories	
Earlier in males					RODENT Rat: Kim & Juraska 1997* (in splenium of the corpus callosum)	
No signif. difference						
Earlier in females						

2.2.4.3. Dendrites/Primary Dendrites, Number of

Dendrites extend from neurons in order to obtain information from other nerve cells, both adjacent and more distant. One study found that female rats had greater numbers of dendrites than did males in one type of hippocampal cells but not in another (Table 2.2.4.3).

Table 2.2.4.3. Dendrites/primary dendrites, number of.

Nature of Any Difference					Postpubertal	
					Adult	
More in males						
No signif. difference					RODENT Rat: E Gould et al. 1990* (on the CA1 pyramidal cells of the hippocampus)	
More in females					RODENT Rat: E Gould et al. 1990* (on the CA3 pyramidal cells of the hippocampus)	

2.2.4.4. Dendritic Lengths

According to one study, no significant sex differences were found in the length of the dendrites, at least within a portion of the hypothalamus, while another study found some differences in the visual cortex of rodents (Table 2.2.4.4).

Table 2.2.4.4. Dendritic lengths.

Nature of Any Difference	Prepubertal		Postpubertal	
	Early Childhood		Adolescent	
More in males				
No signif. difference			RODENT Rat: Juraska 1990 (length of dendritic trees & lengths of segments in the granule cells of the dentate gyrus of the hippocampus)	
More in females	RODENT Rat: Seymoure & Juraska 1992 (at weaning, in the monocular subfield of the visual cortex neurons)			

2.2.4.5. Dendritic Segments, Numbers of

According to one study among rats, females have a greater number of dendritic segments than do males (Table 2.2.4.5).

Table 2.2.4.5. Dendritic segments, numbers of.

Nature of Any Difference					Postpubertal	
					Adolescent	
More in males						
No signif. difference						
More in females					RODENT <i>Rat</i> : Juraska 1990 (in granule cells of dentate gyrus-hippocampus)	

2.2.4.6. Dendritic Spines/Dendritic Branching, Number of

Often extending from the primary trunk of a dendrite are several secondary branches or spines. As shown in Table 2.2.4.6, several studies of various species of rodents have concluded that among adults, greater dendritic branching is found in the neurons of males than of females. However, among prepubertal animals, this pattern is not found.

Table 2.2.4.6. Dendritic spines/dendritic branching, number of.

Nature of Any Difference	Prepubertal		Postpubertal	
	Infant	Early Childhood	Adult	
More in males			RODENT <i>Hamster</i> : Greenough et al. 1977 (in the POA of the hypothalamus); <i>Meadow Vole</i> : Kavaliers et al. 1998 (in parietal and prefrontal cortex); <i>Mouse</i> : Juraska et al. 1985 (in the hippocampus); Juraska et al. 1989 (in the hippocampus); <i>Rat</i> : Raisman & Field 1973 (in the POA of the hypothalamus); Madeira et al. 1991 (in the hippocampus); Parducy & Garcia-Segura 1993 (in the hippocampus); Rasia-Filho et al. 2004 (in the medial region of the amygdala)	
No signif. difference	RODENT <i>Rat</i> : Munoz-Cueto et al. 1990 (postnatal day 10, in the visual cortex)			
More in females		RODENT <i>Rat</i> : Seymoure & Juraska 1992 (at weaning, longer bifurcating of the visual cortex neurons)		

2.2.4.7. Changes in Dendritic Spines With Age

One study of rats concluded that the number of dendritic spines increased with age more in males than in females; in fact, females actually exhibited a decrease during the same time frame (Table 2.2.4.7).

Table 2.2.4.7. Changes in dendritic spines with age.

Nature of Any Difference					Multiple Age Categories	
Greater increase in males					RODENT <i>Rat</i> : Munoz-Cueto et al. 1990 (from postnatal days 20 through 60 s 10, pyramidal cells in the visual cortex)	
No signif. difference						
Greater increase in females						

2.2.4.8. Changes in Dendritic Structures in Response to Environmental Complexity

One study of rats suggested that males exhibited a greater increase in the length and degree of branching of dendrites in their visual cortex relative to females when both were exposed to equal degrees of environmental enrichment (Table 2.2.4.8).

Table 2.2.4.8. Changes in dendritic structures in response to environmental complexity.

Nature of Any Difference					Postpubertal	
					Adult	
More in males					RODENT <i>Rat</i> : Juraska 1984 (dendritic branching and lengths in the visual cortex)	
No signif. difference						
More in females						

2.2.4.9. Mossy Fiber Synapses

There are two mossy fiber systems in the mammalian brain, one in the hippocampus and one in the cerebellum. Granule cells in the dentate gyrus (a part of the hippocampus) send axons, the mossy fibers, to the CA3 region of the hippocampus. Given the role of the hippocampus in memory and emotion, it seems likely that mossy fiber systems may facilitate these functions. Studies have reached inconsistent conclusions about any sex differences in the prevalence or in the forms of mossy fiber synapses among rats (Table 2.2.4.9).

Table 2.2.4.9. Mossy fiber synapses.

Nature of Any Difference					Postpubertal
					Adult
More in males					RODENT Rat: Parducz & Garcia-Segura 1993 (in the hilus of dentate gyrus of the hippocampus); Madeira et al. 1995* (Sprague-Dawley rats; volume of mossy fiber system)
No signif. difference					RODENT Rat: Madeira et al. 1995* (Sprague-Dawley rats; total number of synapses in the dentate gyrus)
More in females					RODENT Rat: Madeira et al. 1995* (Sprague-Dawley rats; density of synapses in the dentate gyrus)

2.2.4.10. Neuronal Nuclei, Diameter of

The cell's nucleus primarily houses its DNA. Two studies of rats found that the nuclei of the neurons within the amygdala and the hypothalamus are larger in males than in females (Table 2.2.4.10). This size difference may reflect differing degrees of information exchanged between the nuclei and their surrounding cytoplasm.

Table 2.2.4.10. Neuronal nuclei, diameter of.

Nature of Any Difference					Postpubertal
					Adult
Larger in males					RODENT Rat: Pfaff 1966 (in the POA of the hypothalamus); Staudt & Dorner 1976 (in the amygdala)
No signif. difference					
Larger in females					

2.2.4.11. Synaptic Junctions, Number of

Findings surrounding any gender differences in the density of synaptic junctions in the brain have come to inconsistent conclusions, at least in the case of rats. The one study of humans found females exhibiting greater density than males (Table 2.2.4.11).

Table 2.2.4.11. Synaptic junctions, number of.

Nature of Any Difference					Postpubertal
					Adult
More in males					RODENT Rat: Matsumoto & Arai 1980* (axosomatic synapses in the arcuate nucleus); Nishizuka & Arai 1981a (young, in the amygdala); Nishizuka & Arai 1981b (young); Guldner 1982; Matsumoto & Arai 1986; Reid & Juraska 1992 (in the binocular visual cortex)
No signif. difference					
More in females					EUROPE Switzerland: Rabinowicz et al. 2002 (young) RODENT Rat: Raisman & Field 1973 (young, nonstriatal synapses in the hypothalamic POA); Matsumoto & Arai 1980* (spine synapses in the arcuate nucleus); Guldner 1982

2.2.4.12. Synaptic Junctions, Length of

One study of the brains of rats concluded that the synaptic junctions between neurons were larger in females than in males (Table 2.2.4.12).

Table 2.2.4.12. Synaptic junctions, length of.

Nature of Any Difference					Postpubertal
					Adult
More in males					
No signif. difference					
More in females					RODENT Rat: SN Reid & Juraska 1992

2.3 NEUROLOGICAL FUNCTIONING

Neurological functioning refers to any electrochemical changes that occur within the brain or spinal cord. A variety of techniques have been developed for monitoring these changes, ranging from relatively simple electroencephalograms (EEGs) to much more complex functional magnetic resonance imaging (fMRIs).

2.3.1. General Neurological Functioning

General neurological functioning can be measured in a number of ways, ranging from the use of electrodes on the scalp to detect brain wave activity to more complex methods of magnetic brain scanning.

2.3.1.1. Brain Waves, Speed of

Brain waves, as measured by electroencephalographs (EEGs), occur at widely varying oscillating rates. One study found that during sleep, male brain waves were faster on average than were those of females, while another study concluded that males exhibited faster brain waves following a period of sleep deprivation than did females (Table 2.3.1.1).

Table 2.3.1.1. Brain waves, speed of.

Nature of Any Difference	Postpubertal	
	Adult	
More rapid in males	ASIA <i>Japan</i> : Fukuda et al. 1999 (during sleep)	NORTH AMERICA <i>United States</i> : R Armitage et al. 2001 (following sleep deprivation)
No signif. difference		
More rapid in females		

2.3.1.2. EEG Power

EEG power (or EEG response amplitude) refers to the overall degree of brain activity as revealed through movements in the electroencephalograph (usually in response to a standard set of testing conditions). According to studies summarized in Table 2.3.1.2, human females exhibit greater EEG power than do males. One study of rats reached the same conclusion at least regarding delta brain waves.

Table 2.3.1.2. EEG power.

Nature of Any Difference	Postpubertal		Multiple Age Categories
	Adult		
Greater in males			
No signif. difference			
Greater in females	EUROPE <i>Spain</i> : Harmony et al. 1990	NORTH AMERICA <i>United States</i> : Jerger 1980 (to acoustic signals); Dijk et al. 1989 (young); R Armitage et al. 1995 (delta waves among depressed persons); Briere et al. 2001 (young, delta waves)	ASIA <i>Japan</i> : Matsura et al. 1985
	RODENT <i>Rat</i> : Juarez et al. 1995 (delta activity in the whole brain)		

2.3.1.3. Theta Brain Wave Activity/Power, Amount of

Several studies that have specifically monitored theta brain wave activity (which tend to be slow relative to alpha and delta waves, the latter being associated with sleep) all concluded that males exhibit more theta wave activity than do females (Table 2.3.1.3).

Table 2.3.1.3. Theta brain wave activity/power, amount of.

Nature of Any Difference					Postpubertal
					Adult
More in males					EUROPE <i>Spain</i> : Lorenzo et al. 1995 LATIN AMERICA <i>Mexico</i> : Corsi-Cabrera et al. 2002 (after prolonged sleep deprivation); Corsi-Cabrera et al. 2003 (after prolonged sleep deprivation) NORTH AMERICA <i>United States</i> : DP Brunner et al. 1993; Dumont et al. 1999; JA Caldwell et al. 2000; Forest & Godbout 2000 (young) RODENT <i>Rat</i> : Juarez et al. 1995 (power in the whole brain)
No signif. difference					
More in females					

2.3.1.4. Amygdala Activation in General

The mammalian amygdala is an almond-shaped structure located deep inside the subcortex on each side adjacent to the temporal lobes of the neocortex. This ancient brain structure plays a key role in regulating emotions. According to two studies, the amygdala of males is more intensely activated during negative emotional experiences than is that of females (Table 2.3.1.4).

Table 2.3.1.4. Amygdala activation in general.

Nature of Any Difference					Postpubertal
					Adult
More in males					NORTH AMERICA <i>United States</i> : Schneider et al. 2000 (when feeling sad); Cahill et al. 2001 (negative emotions, PET scan)
No signif. difference					
More in females					

2.3.1.5. Auditory Evoked Response

The auditory evoked response (AER) refers to specific types of brain wave patterns resulting from performance of various auditory tasks. Table 2.3.1.5 suggests that females exhibit greater AERs under standard testing conditions than do males.

Table 2.3.1.5. Auditory evoked response.

Nature of Any Difference					Postpubertal
					Adult
Greater in males					
No signif. Difference					
Greater in females					NORTH AMERICA <i>United States</i> : Buchsbaum & Silverman 1968 (hypersensitive AER amplitude); Hetrick et al. 1996 (magnitude); Rojas et al. 1999 (lingering of the M100 AER)

2.3.1.6. Event-Related Potential

Event-related potential (ERP) involves the averaging of brain wave response patterns to multiple specific stimuli presented to subjects at irregular intervals. One study of subjects performing a mental rotation task concluded that males and females were statistically equivalent in the ERP response patterns (Table 2.3.1.6).

Table 2.3.1.6. Event-related potential.

Nature of Any Difference					Postpubertal
					Adult
Greater in males					
No signif. difference					NORTH AMERICA <i>Canada</i> : Desrocher et al. 1995:13 (during a mental rotation task)
Greater in females					

2.3.1.7. Cerebellar Activity

The cerebellum is a structure at the posterior of the mammalian brain that specializes in performing certain coordination skills. According to one study, men exhibit more cerebellar activation than women when both are trying to perform a task involving remembering specific pitches (Table 2.3.1.7).

Table 2.3.1.7. Cerebellar activity.

Nature of Any Difference					Postpubertal
					Adult
More in males					
No signif. difference					
More in females					MIDDLE EAST <i>Israel</i> : Gaab et al. 2003 (pitch memory task)

2.3.1.8. Neocortical Control Over Subcortical Brain Activity

Two of three research findings concerning which sex uses regions of the neocortex to alter or suppress subcortical activity have concluded that females do so to a greater extent than males (Table 2.3.1.8).

Table 2.3.1.8. Neocortical control over subcortical brain activity.

Nature of Any Difference					Postpubertal	Multiple Age Categories
					Adult	
Greater in males					ASIA <i>Japan</i> : Shirao et al. 2005 (young, prefrontal cortical activation when listening to unpleasant words concerning body image)	
No signif. difference						
Greater in females					OCEANIA <i>Australia</i> : AH Kemp et al. 2004 (young, reduced latency of discharge by frontal lobes to unpleasant images)	NORTH AMERICA <i>United States</i> : Kilgore et al. 2001 (children & adolescents, frontal lobes dampen amygdala activity)

2.3.1.9. Subcortical (Versus Neocortical) Brain Activity

A few studies have compared the degree to which the subcortex is activated when subjects are given various cognitive or perceptual tasks. As shown in Table 2.3.1.9, males appear to activate various subcortical regions to a greater extent than females when they are required to process emotion-provoking or sexual stimuli. However, one study that required a sample of both sexes to listen to unpleasant words having to do with body image found greater female than male activation of the amygdala.

Table 2.3.1.9. Subcortical (versus neocortical) brain activity.

Nature of Any Difference					Postpubertal
					Adult
Greater in males					EUROPE <i>Germany</i> : F Schneider et al. 2000 (college, amygdala activation when processing sadness-evoking stimuli) NORTH AMERICA <i>United States</i> : Kilgore & Yurgelin-Todd 2001 (amygdala activation to emotion-provoking stimuli); Karama et al. 2002 (college, hypothalamus & thalamus activation to sexual stimuli)
No signif. difference					
Greater in females					ASIA <i>Japan</i> : Shirao et al. 2005 (young, amygdala activation when listening to unpleasant words concerning body image)

2.3.1.10. GABAergic Brain Activity

GABA is a major and largely inhibitory transmitter in the brain. Unusual GABAergic organization has been associated with epilepsy and schizophrenia. One study indicated that among rats, greater GABAergic brain activity was taking place in males than in females (Table 2.3.1.10).

Table 2.3.1.10. GABAergic brain activity.

Nature of Any Difference					Postpubertal
					Adult
More in males					RODENT <i>Rat</i> : Grattan & Selmanoff 1997 (in medial preoptic nucleus and ventro-medial nucleus)
No signif. difference					
More in females					