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Gendered Innovations

How Gender Analysis Contributes to Research

Research and Innovation

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EUROPEAN COMMISSION

Gendered Innovations

How Gender Analysis Contributes to Research

Report of the Expert Group "Innovation through Gender"
Chairperson: Londa Schiebinger
Rapporteur: Ineke Klinge

2013 Directorate General for Research & Innovation EUR 25848

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Foreword

It may surprise you that opinion polls suggest that women are less interested in innovations than men, but personally I find it difficult to accept that this could be due to a fundamental difference between women and men. The explanation must surely be elsewhere: do today's innovations really respond adequately to women's needs and expectations? Not always! The diagnosis of heart disease draws heavily on research carried out using male patients and consequently women's symptoms are often misdiagnosed; car safety tests are based mostly on male standards and the deleterious effects of chemicals in the environment on reproductive health have also been studied predominantly in men.

With this in mind, in 2011 the European Commission established an expert group 'Innovation Through Gender' to conduct a comprehensive review of this domain. The group involved more than sixty experts from across Europe, the United States, and Canada. The experts chose to go beyond simply pointing at loopholes and flaws, and instead looked at concrete examples of where appropriate treatment of gender differences enhances research. This is why the report will have real impact. For example, the report highlights how studying sex differences in animal models could lead to new post-traumatic brain injury treatments. It shows that innovative assistive technologies can be developed from a better knowledge of how elderly women as well as men interact with their local environments. And even at the most fundamental level, understanding sex differences in cell-based research will improve clinical guidelines for stem cell therapies.

The case studies presented in this report demonstrate that differences between the needs, behaviours and attitudes of women compared to men really matter, and accounting for them in research makes it relevant to the whole of society. They also show that these differences can vary over time and across different sectors of society and require specific analyses.

The report provides scientists and engineers with practical tools for gender analysis which help them rethink concepts, formulate relevant questions and develop appropriate methods. The report also offers recommendations to research funding agencies, research institutions, heads of higher education establishments, industries, journal editors and other interested parties.

As the EU Commissioner for Research, Innovation and Science, I am determined to strengthen the gender dimension in the new EU Research and Innovation Programme, Horizon 2020, which will start in 2014. It is crucial that EU Member States make sure that their national R&I programmes also take account of this dimension. In this way, together we can take great strides towards a reinforced European Research Area for excellence and growth. It really is a win-win situation: gender analysis contributes to excellence; it stimulates new knowledge creation and technologies; opens new niches and opportunities for research teams and results in products and services that all members of society need and demand.

Innovation lies at the heart of the Europe 2020 Strategy for smart growth, and the Innovation Union flagship aims at making Europe a global leader in solving societal challenges. It is, therefore, essential to support innovations that improve the lives of women as well as men. This report proves that effective action can be taken. I highly commend it.

Máire GEOGHEGAN-QUINN

Executive Summary

In February 2011 the European Commission convened an Expert Group, "Innovation through Gender," to help develop the gender dimension in EU research.

The work was initiated at Stanford University in July 2009. In 2011 and 2012, the Directorate-General for Research & Innovation of the European Commission (EC) funded the Expert Group within its work programme Science in Society of the Seventh Framework Programme for Research and Technological Development (EU FP7).

The goal of the Expert Group was twofold: to provide scientists and engineers with practical methods for sex and gender analysis, and to develop case studies as concrete illustrations of how sex and gender analysis leads to new ideas and excellence in research.

To match the global reach of science and technology, the case studies and methods of sex and gender analysis were developed through European and international collaborations. The Expert Group consisted of more than sixty experts from across Europe, the United States, and Canada. Experts met in a series of peer-reviewed, interdisciplinary workshops, representing a unique collaboration between gender experts and experts in each technical field treated. Seven workshops were held in following places: Stanford University (February 2011); Fraunhofer, Berlin (March 2011); Maastricht University (July 2011); Ministry for Higher Education and Research, Paris (March 2012); Spanish National Cancer Research Center, Madrid (May 2012); Harvard University (July 2012); and Spanish National Research Council, Brussels (September 2012). Support was also provided to some of the US experts by the US National Science Foundation in 2012. Case studies were selected through the advice of the Expert Group and through collaborations with the EU FP7 project coordinators. A full list of experts can be found in Annex D of this report.

The case studies offer new insights in basic science, engineering & technological development, environment, food & nutrition, health & medicine, transport, as well as communicating science. These fields reflect priorities set in the new European Framework Programme Horizon 2020 that will cover the period 2014-2020.

The group was led by

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Globally Accessible, Peer-Reviewed Gendered Innovations Websites:
http://www.ec.europa.eu/research/swafs/gendered-innovations/index_en.cfm
http://genderedinnovations.stanford.edu/

What is Gendered Innovations?

Thirty years of research have revealed that sex and gender bias is socially harmful and expensive. Gender bias also leads to missed market opportunities. In engineering, for example, assuming a male default can produce errors in machine translation. In basic research, failing to use appropriate samples of male and female cells, tissues, and animals yields faulty results. In medicine, not recognizing osteoporosis as a male disease delays diagnosis and treatment in men. In city planning, not collecting data on caregiving work leads to inefficient transportation systems.

It is crucially important to identify gender bias and understand how it operates in science and technology. But analysis cannot stop there. Gendered Innovations offer sophisticated methods of sex and gender analysis to scientists and engineers. Integrating these methods into basic and applied research produces excellence in science, health & medicine, and engineering research, policy, and practice.[1]

Gendered Innovations:

- **Add value to research and engineering** by ensuring excellence and quality in outcomes and enhancing sustainability.
- **Add value to society** by making research more responsive to social needs.
- **Add value to business** by developing new ideas, patents, and technology.

1 For a background paper, see L. Schiebinger and M. Schraudner, Interdisciplinary Approaches to Achieving Gendered Innovations in Science, Medicine, and Engineering. *Interdisciplinary Science Reviews*, 36, no. 2 (2011), 154-167.

Glossary

See Annex A for more details.

Sex refers to biological qualities characteristic of women [females] and men [males] in terms of reproductive organs and functions based on chromosomal complement and physiology. As such, sex is globally understood as the classification of living things as male and female, and intersexed.

Gender—a socio-cultural process—refers to cultural and social attitudes that together shape and sanction "feminine" and "masculine" behaviours, products, technologies, environments, and knowledge.

Gender analysis is presented in twelve methods in this project. Researchers may analyze sex or analyze gender. Gender analysis is the umbrella term for the entire process. Researchers will consider each of the twelve methods and choose the interacting methods that apply to their particular project.

Innovation in this project refers to new ideas, new knowledge, and new technologies and design.

Gendered Innovations are defined as processes that integrate sex and gender analysis into all phases of basic and applied research to assure excellence and quality in outcomes.

ACRONYMS

EU FP7: Seventh Framework Programme for Research and Technological Development

List of All Case Studies

The case studies[2] demonstrate—in concrete ways—how harnessing the power of sex and gender analysis creates Gendered Innovations—that is, new knowledge or technologies.

BASIC SCIENCE

Animal Research: Designing Health and Biomedical Research

Brain Research: Analyzing How Sex and Gender Interact

Genetics of Sex Determination: Rethinking Concepts and Theories

Stem Cells: Analyzing Sex

COMMUNICATING SCIENCE

Textbooks: Rethinking Language and Visual Representations

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Housing and Neighborhood Design: Analyzing Gender

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HEALTH & MEDICINE

De-Gendering the Knee: Overemphasizing Sex Differences as a Problem

Heart Disease in Women: Formulating Research Questions

Osteoporosis Research in Men: Rethinking Standards and Reference Models

TRANSPORT

Human Thorax Model: Rethinking Standards and Reference Models

Information for Air Travellers: Participatory Research and Design

Pregnant Crash Test Dummies: Rethinking Standards and Reference Models

Public Transportation: Rethinking Concepts and Theories

2 All case studies referenced in this report are available on the Gendered Innovations website. Twenty-one abstracts are reproduced below and eight sample case studies in Annex B.

Abstracts of Twenty-One Gendered Innovations Case Studies

BASIC SCIENCE

Animal Research: Designing Health & Biomedical Research

The Challenge

Most basic research with animal models focuses on males and excludes females (Zucker et al., 2010; Marts et al., 2004). This creates three problems:

1. Less knowledge about disease processes in females due to underutilization of female animals. Results of studies in males are often generalized to females without justification, and even some conditions that occur more often in women are studied in mostly male animals. A gap exists between the proportion of women in patient populations and the proportion of female animals used in testing.
2. Inability to use sex as a variable in studies of basic biology (Holdcroft, 2007). In many cases, sex has proven an important variable—for example, in regulation of immune function.
3. Missed opportunities to examine female-specific phenomena (such as pregnancy and, in some species, menopause) that often interact with disease progression. Studying pregnancy in model organisms is especially important, given the safety concerns about testing in pregnant women.

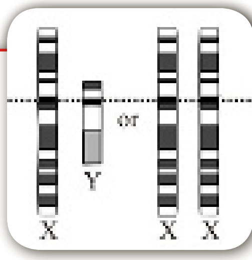
Method: Designing Health and Biomedical Research

National legislation typically requires inclusion of women in government-sponsored human studies. For example, the US National Institutes of Health require "that women and members of minorities and their subpopulations" be included in all human subjects research (although sufficient representation of women to allow for sex analysis is required only for Phase III clinical trials—see Gendered Innovations website, Policy Recommendations, Policy Timeline). These guidelines, however, rarely apply to studies conducted on animals, even though sampling animals of both sexes and of various hormonal states has produced new discoveries that influence drug development and patient care.

Gendered Innovations:

1. **Studying sex differences in animal models** has led to new treatments for traumatic brain injury (TBI).
2. **Accounting for pregnancy, estrous cycle, and menopausal status** in animal models has revealed the biological influence of hormones on basic molecular pathways and has been important to understanding certain autoimmune diseases.
3. **Regulators have considered sex** in order to improve animal models for toxicity; this has led to stronger environmental health standards.

The Genetics of Sex Determination: Rethinking Concepts and Theories



The Challenge

Research into sex determination formerly focused primarily on testis development, and active processes controlling ovarian development were largely ignored (Veitia, 2010). Ovarian development was long considered a "default" or "passive" developmental outcome of the bipotential gonad.

Method: Rethinking Concepts and Theories

The notion of a "default" female pathway focused research on testis differentiation, and after the discovery of Sry, on the downstream targets of Sry (e.g., Sox9). In contrast, the ovarian pathway was less explored. Scientific models portraying the female developmental pathway as a "default" were inconsistent with lack of ovarian development in Turner's syndrome, among other issues.

Gendered Innovations:

1. **Recognition of Ovarian Determination as an Active Process.** Current research is identifying the active mechanisms required to produce an ovary (Veitia, 2010; Uhlenhaut et al., 2009). These investigations have enhanced knowledge about testis development and how the ovarian and testicular pathways interact.
2. **Discovery of Ongoing Ovarian and Testis Maintenance.** Research into the ovarian pathway revealed that the transcriptional regulator FOXL2 must be expressed in adult ovarian follicles to prevent "transdifferentiation of an adult ovary to a testis" (Uhlenhaut et al., 2009). Subsequently, researchers found that the transcription factor DMRT1 is needed to prevent reprogramming of testicular Sertoli cells into granulosa cells (Matson et al., 2011).
3. **New Language to Describe Gonadal Differentiation.** Researchers have dismissed the concept of "default" and now emphasize that, athough female and male developmental pathways diverge, the construction of an ovary (like the construction of a testis or any other organ) is an active process. Each pathway requires complex cascades of gene products in proper dosages and at precise times.

Stem Cells: Analyzing Sex

The Challenge

Biological sex is commonly studied as a variable in research with humans, but analyzing sex is rare in animal research and rarer still in cell-based research (Beery et al., 2011). This deficiency can represent a lost opportunity to understand basic and developmental biology, and to refine cell-based therapies.

Method: Analyzing Sex

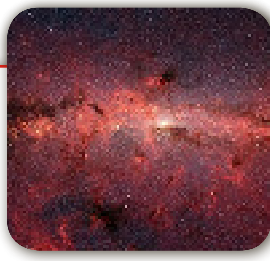
Sex should be analyzed at all levels, from chromosomes and cells to whole organisms. Taking sex into account has led to novel questions about stem cells. Analyzing sex involves:

1. Designing research to use cells of both sexes in sufficient quantities to detect or rule out sex differences (not all sex differences will be significant).
2. Reporting the sex of cells used in experiments.
3. Recording, formatting, and analyzing data to allow for meta-analysis. Reviews can identify gaps in knowledge (when, for example, experiments have involved cells of only one sex). Meta-analysis can increase statistical power and may allow sex analysis even in the absence of two-sex studies.

Gendered Innovations:

1. **Identifying Sex Differences in Stem Cell Characteristics**. Research using animal models has shown that the sex of stem cells may influence therapeutically relevant cell traits, such as proliferation and differentiation rates.
2. **Understanding Differences within and between XX and XY Stem Cells**. Discoveries about interactions between genetics, hormonal environments, and epigenetics have improved the understanding of stem cell biology.
3. **Improving Clinical Guidelines for Stem Cell Therapies**. By formulating research questions about the importance of donor and recipient sex (along with other factors that interact with sex) in hematopoietic stem cell transplantation, researchers have gathered data relevant to improving clinical guidelines for this stem cell therapy.

COMMUNICATING SCIENCE



Textbooks: Rethinking Language and Visual Representations

The Challenge

Textbooks carry core knowledge to students in science and engineering. Further, textbooks shape impressions of the nature of scientific work—impressions about who becomes a scientist or what kinds of problems engineers work to solve. Textbooks that embed stereotypes of sex and gender in materials perpetuate gender assumptions and produce unsound science.

Method: Rethinking Language and Visual Representations

Language (word choice, metaphors, analogies, and naming practices) and visual **representations** (images, tables, and graphs) have the power to shape scientific practice, the questions asked, the results obtained, and the interpretations made. Rethinking language and visual representation in textbooks can help remove unconscious gender assumptions that restrict discovery and innovation, and thereby reduce gender inequalities.

Gendered Innovations:

1. **Revising biology textbooks to incorporate new findings from sex and gender research**. In developmental biology, revision includes expanding accounts of human fertilization to reflect the active role played by the female reproductive system in sperm transport and capacitation. In bacteriology, it includes removing scientifically unsound metaphors that present bacteria as sexed organisms.
2. **Revising physics textbooks to illustrate scientific principles through more gender-neutral examples.**

ENGINEERING & TECHNOLOGICAL DEVELOPMENT

Exploring Markets for Assistive Technologies for the Elderly: Engineering Checklist

The Challenge

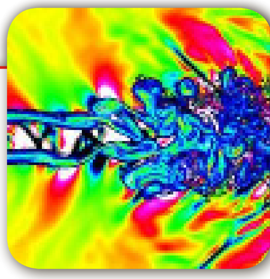
The world's population will age dramatically by 2050. The increasing need for ambulant care and home health services places a growing strain on human caregivers, insurance companies, and social systems. New technologies are needed to support independent living for the elderly.

Method: Engineering Checklist

Applying sex and gender analysis to data related to elder care reveals new opportunities for assistive technologies and robotics. Researchers have studied the differing needs of women and men as they age. This research, along with collaboration with the elderly, their caregivers, and other stakeholders, provide engineers with insights for designing and developing assistive products that are useful to a broad user base.

Gendered Innovations:

1. **Assessing Women's and Men's Needs for Assistive Technologies**
2. **Developing Assistive Technologies Considering Women's and Men's Needs**
3. **Using Participatory Design to Create the Next Generation of Assistive Technology**



HIV Microbicides: Rethinking Research Priorities and Outcomes

The Challenge

Engineering is a field where—despite national and international efforts—women remain underrepresented. Many schemes exist to increase women's participation, but few have considered how research foci, funding decisions, and project objectives affect women and men's proportional participation in research.

Method: Rethinking Research Priorities and Outcomes

This case study analyzes how a shift in research priorities in a particular mechanical engineering lab led to increased numbers of women working in the lab. Women were drawn to applied physicist Andrew Szeri's lab when research came to focus on the fluid mechanics of gels to deliver woman-controlled HIV microbicides. Increasing women's participation in engineering may require reconceptualizing research to include methods of sex and gender analysis in creative and forward-looking ways.

Gendered Innovations:

1. **The proportion of women in one mechanical engineering lab was significantly increased** when research priorities were changed to focus on projects with direct potential to improve human health. At the same time, this change in priorities expanded research in the field of fluid mechanics.
2. **Woman-controlled HIV protection** is being developed in order to assist women in cultures where they may have less power to say "no" to sex or cannot rely on their partners to use condoms. This new technology represents an innovation that could help prevent the spread of HIV.
3. **Understanding how sexual practices differ across cultures** is further refining developments in HIV prevention. These developments could help sub-Saharan women and also men who have sex with men.

Machine Translation: Analyzing Gender

The Challenge

Machine translation (MT) becomes increasingly important in a globalize world. Although error rates are still high, MT system accuracies are improving incrementally. Some errors in current systems, however, are based on fundamental technological challenges that require non-incremental solutions. One such problem is related to gender: State-of-the-art translation systems like Google Translate or Systran massively overuse masculine pronouns (he, him) even where the text specifically refers to a woman (Minkov et al., 2007). The result is an unacceptable infidelity of the resulting translations and perpetuation of gender bias.

Method: Analyzing Gender

The reliance on a "masculine default" in modern machine translation systems results from current systems that do not determine the gender of each person mentioned in a text. Instead, the translation is produced by finding all the possible matches for a given phrase in large collections of bilingual texts, and then choosing a match based on factors such as its frequency in large text "corpora" (or bodies of text). Masculine pronouns are over-represented in the large text corpora that modern systems are trained on, resulting in over-use in translations. In July 2012 the Gendered Innovations project convened a workshop to discuss potential solutions. Improving feminine-masculine pronoun balance in these corpora, for example, would still not fix the problem, since it will simply cause both women and men to be randomly referred to with the wrong gender. Instead, it is crucial to develop algorithms that explicitly determine the gender of each person mentioned in text and use this computed gender to inform the translation. Such algorithms could avoid the masculine default and also increase the quality of translation overall.

Gendered Innovations:

1. **Studying the Male Default in Machine Translation**
2. **Detecting the Gender of Entities to Improve Translation Algorithms (research in progress)**

Making Machines Talk: Formulating Research Questions

The Challenge

Speech synthesis—in which a machine generates human-like speech—has applications in basic linguistic research, assistive technologies for people with disabilities, and commercial devices and software. Of particular interest are text-to-speech (TTS) systems. Mute people who rely on speech synthesis to express themselves are best served by synthesizers capable of producing a range of women's and men's voices: Synthesizing sex and gender in speech is important to how speech is perceived and interpreted (Nass et al., 2005).

Method: Analyzing Gender

Gender assumptions can influence both the act of speaking and the act of listening (or interpreting what is heard) even when the speaker is a machine. Voices encode rich information about the speaker—such as sex, gender, age, and often nationality—even if such information is never directly articulated. Analyzing sex (biological factors) and gender (socio-cultural factors) is important for creating TTS systems with a range of voices for assistive technologies and other human/computer interfaces.

Gendered Innovations:

1. **Text-to-Speech Technologies Producing both Women's and Men's Voices.** Text-to-speech system engineers who rethought research priorities and outcomes and recognized the importance of producing both women's and men's voices created new products, such as DECTalk (1984). Flexible speech synthesizers capable of producing voices representing women and men of different ages, gender identities, and regional dialects help fit voice characteristics to users.
2. **Understanding Gender in Speech.** By analyzing gender, researchers better understand how social identities are communicated in speech. Computerized TTS systems are effectively social actors, and the messages they send depend on the underlying technology, uses, and users' responses.

Nanotechnology-Based Screening for HPV: Rethinking Research Priorities and Outcomes

Abstract

This case study examines the "Enhanced Sensitivity Nanotechnology-Based Multiplexed Bioassay Platform for Diagnostic Applications" (NANO-MUBIOP) project, funded by EU FP7. We identify gendered innovations, methods of sex and gender analysis, and points of potential "value added."

The Challenge

Infection with Human Papillomavirus (HPV) "is estimated to cause [...] 100% of cervical cancer cases." It also contributes to the incidence of other cancers affecting both women and men, including anal cancer, oral and oropharyngeal cancers, and other cancers of the genitals (WHO, 2008b). Worldwide, cervical cancer causes about 275,000 deaths per year—80% in countries with limited medical resources (Sankaranarayanan et al., 2012). Existing HPV tests offer good sensitivity and specificity but are rarely used in developing countries because of cost (Cuzick et al., 2008). A low-cost, high-performance test could improve healthcare in developing countries.

Method: Rethinking Research Priorities and Outcomes

In designing a new diagnostic technology, the NANO-MUBIOP project prioritized characteristics that would encourage adoption in low-resource areas, such as Latin America and the Caribbean, sub-Saharan Africa, Melanesia, and South-Central and South-East Asia. New diagnostics include technical characteristics (e.g., the ability to differentiate between specific types of HPV) and logistical characteristics (e.g., low overhead cost).

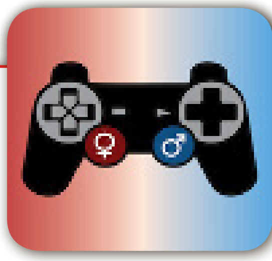
Gendered Innovations:

Developing a Low-Cost HPV Screening Test. NANO-MUBIOP seeks to develop a platform for inexpensive HPV testing.

Potential Value Added to Future Research through the Application of Gendered Innovations Methods:

1. Identifying potential users of the NANO-MUBIOP platform.
2. Understanding the causes of poor cervical cancer screening coverage.

Video Games: Engineering Innovation Processes



The Challenge

During the past 50 years, most video game inventors, programmers, and players have been men. Moreover, the stereotype of gaming as masculine persists, even though women have become active gamers. This stereotype is cause for concern because games immerse players in interactive and compelling stories that can shape behaviours, social values, and gender norms.

Method: Engineering Innovation Processes

Designers market games to girls through several different strategies: 1) They develop games for "everybody." These, by default, are most often designed for boys, who represent the prime market for games. This strategy—aligned with liberal feminism—encourages girls to develop the skills needed to play male-oriented games. 2) They design games specifically for girls—an approach based on difference feminism, which can promote gender stereotypes and essentialism, and which may overemphasize gender differences between girls and boys, women and men. 3) A third approach—presented here—offers designers methods for designing games with dynamic—not prescriptive or stereotypical—gender norms. Analyzing gender assumptions can lead to designing virtual spaces where players can explore gender identities and behaviours.

Gendered Innovations:

1. **Games may serve as catalysts for change.** Analyzing gender has led to understanding how games provide a virtual space where designers and players can explore gender identities and behaviours. Challenging gender stereotypes may enhance diversity in video and online games, and potentially the gaming industry itself. This is important because games are increasingly spaces where young people socialize.
2. **Designers can create flexible, gender-mixed games.** By analyzing gender throughout engineering innovation processes, researchers have looked beyond stereotypes to understand the complex patterns of young women's and young men's gaming—patterns that are influenced by factors beyond gender, such as age, experience, and geographic location.

Water Infrastructure: Participatory Research and Design

The Challenge

Nearly one billion people worldwide lack reliable access to clean water (Hunter et al., 2010). In sub-Saharan Africa, water-fetching is women's work, and when villages lack water infrastructure, women and girls spend some 40 billion hours annually procuring water (Hutton et al., 2007).

Method: Participatory Research and Design

Because water procurement is women's work, many women have detailed knowledge of soils and their water yields. This knowledge is vital to civil engineering and development projects—for instance, in determining where to place wells and water taps.

Gendered Innovations:

1. **Tapping into local women's knowledge has improved the efficiency of water projects.** A study of water projects in 13 nations revealed that "equal [...] participation by women contributes to the success of community-managed water services" (Postma et al., 2003). Women's participation also correlates strongly with project sustainability (Gross et al., 2001).
2. **Easy access to improved water supplies can improve school attendance for both girls and boys**—hence helping to break the cycle of poverty.

ENVIRONMENT

Climate Change: Analyzing Gender, and Factors Intersecting with Gender

The Challenge

The European Union has the ambitious goal of reducing its greenhouse gas emissions to 20% below 1990 levels by 2020 (European Commission, 2010). The US supports emissions reduction through funding for alternative energy research, but has not legislated limits for total greenhouse gas emissions (Gurgel et al., 2011; Dixon et al., 2010). Both the EU and US also have far-reaching goals for gender equality, but how these two important challenges—climate change and gender equality—might be related is rarely considered (European Commission, 2012; US Equal Employment Opportunity Commission, 2012).

Methods: Analyzing Gender, and Analyzing Factors Intersecting with Gender

Research on the relationship between gender and environmental impact is still in its infancy. Analyzing gender, in this instance, means comparing women's and men's behaviours and attitudes in relation to climate change. But researchers must ask: Which women? Which men? and compare groups of women and men based on social factors that also predict climate footprint, such as income, educational background, and geographic location. Viewing women as an undifferentiated group and opposing this to men as an undifferentiated group (simply disaggregating data by sex) misses important factors that influence gendered behaviours. Studies that analyze gender and control for other social factors avoid stereotypes and false correlations.

Gendered Innovations:

Understanding the Importance of Analyzing Gender in Relation to Intersecting Factors

Environmental Chemicals: Designing Health & Biomedical Research

This case study examines the "Reproductive Effects of Environmental Chemicals in Females" (REEF) project, funded by EU FP7. We identify gendered innovations, methods of sex and gender analysis, and points of potential "value added" through the future application of gendered innovation methods.

The Challenge

The potential effects of environmental chemicals (ECs) on human reproductive health have been studied predominantly in men. An expert group reporting to the World Health Organization states that "changing trends in female reproductive health have been much less studied than those in males," despite the fact that "female reproductive development is also susceptible to endocrine interference" (Damstra et al., 2002).

Method: Designing Health and Biomedical Research

Researchers have designed experiments to close gaps in scientific knowledge of the potential effects of ECs on female reproductive health. Sampling female animals in controlled experiments has created knowledge regarding physiological and genetic outcomes of EC exposure. Researchers have also sampled pregnant female animals, allowing the use of pregnancy outcomes as endpoints. Further, studying pregnant females has uniquely allowed researchers to investigate the effects of EC exposure on both female and male fetuses in utero and to elucidate sex differences in sensitivity.

Gendered Innovations:

1. **The REEF project focused on the effects of environmental chemical exposure on pregnant females and on their female and male offspring.**
2. **By analyzing sex, the REEF project compared EC effects in utero on females and males, including humans.** Further, post-natal animal studies have potential significance for monitoring EC effects in humans.

Potential Value Added to Future Research through the Application of Gendered Innovation Methods

1. **Investigating possible interactions between pregnancy and EC effects.**
2. **Understanding the influence of sex, age, occupation, geographic location, socioeconomic status, diet, and body composition in potential EC effects on humans.**

FOOD & NUTRITION

Nutrigenomics: Analyzing Factors Intersecting with Sex and Gender

The Challenge

The World Health Organization (WHO) states that non-communicable diseases (NCDs), such as cardiovascular disease, cancers, and diabetes, "are the leading cause of death in the world today" and that modifiable risk factors, such as unhealthy diet, physical inactivity, and tobacco use, are responsible for the majority of NCDs (WHO, 2009). The prevalence of these risk factors, however, vary between "country income groups, with the pattern of variation differing between risk factors and with gender" (WHO, 2011). The bases for this variability are multiple and still poorly defined.

Method: Analyzing Factors Intersecting with Sex and Gender

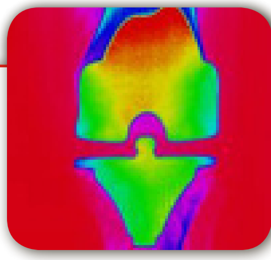
Accounting for gender and other intersecting social factors that make women and men vulnerable to NCDs allows researchers and policy-makers to develop more successful interventions. Analyzing the interaction of sex-specific biological factors and gender-related social factors allows researchers to better understand complex disease patterns and counteract them.

Gendered Innovations:

1. **Understanding Sex- and Gender-Related Variations in NCDs Risk Factors.** Integrating sex and gender analysis into a life course approach helps researchers understand risks for developing NCDs over time.
2. **Determining Sex-Specific Metabolism, Dietary, and Nutrient Responses.** Integrating sex analysis into the field of nutrigenomics provides an understanding of how diets affect females and males at the genetic, molecular, and cellular levels.
    a. **Sex-Specific Metabolism**
    b. **Sex-Specific Dietary Responses**
    c. **Sex-Specific Nutrient Responses**

HEALTH & MEDICINE

De-Gendering the Knee: Overemphasizing Sex Differences as a Problem



The Challenge

In 2007, an estimated 500,000 total knee arthroplasty (TKA) procedures were performed worldwide—about two-thirds in women (Kurtz et al., 2011; Blunt et al., 2008). In the 1990s, with increased attention to women's health research, manufacturers began producing "gender-specific" knees, marketed directly to women. Does this change lead to better healthcare quality?

Term: Overemphasizing Sex Differences as a Problem

Overall, there is a lack of evidence that female-specific prostheses improve women's TKA outcomes (Jacobs et al., 2007). Overemphasizing sex differences is a problem, especially when companies market female-specific knees directly to women without evidence of clinical advantages. Such overemphasis could result in over-reliance on sex as a variable in choosing a knee implant for a given patient when in reality height is a better predictor of morphology. Further, because knee morphology differs within a sex, the "female" knee may be a poor fit for some women and a good fit for some men (Blaha et al., 2009).

Gendered Innovations:

1. **Examining Sex within the Context of other Variables.** Although sex-specific prosthesis design remains controversial, analyzing how sex intersects with other important variables (such as height, ethnicity, and body composition) represents a gendered innovation (Bellemans et al., 2010). Such research raises awareness of differences and questions the "neutrality" of a white male standard model of medicine. Analyzing sex in relation to other variables helps ensure research quality and patient safety.

Heart Disease in Women: Formulating Research Questions

The Challenge

Ischemic heart disease (IHD) is the number one killer of US and European women (WHO, 2008). Nonetheless, heart disease has been defined as primarily a male disease, and "evidence-based" clinical standards have been based on male pathophysiology and outcomes. As a result, women are often mis- and under-diagnosed (Regitz-Zagrosek, 2011).

Method: Formulating Research Questions

Improving women's healthcare has required scientific and technical breakthroughs. It has also required new social, medical, and political judgments about women's social worth, and a new willingness to support women's health and well-being. Analyzing sex and gender in heart disease has required formulating new research questions about disease definitions, symptoms, diagnosis, prevention, and treatments. Once sex and gender were factored into the equation, knowledge about heart disease increased dramatically. As is often the case, including women subjects—of diverse social and ethnic backgrounds—in research has led to a better understanding of disease in both women and men.

Gendered Innovations:

Research on heart disease offers one of the most developed examples of gendered innovation. From the expanding literature on sex and gender analysis in this area, we highlight several pivotal developments:

1. **Redefining the pathophysiology of IHD.** Analyzing sex in clinical research has led to an understanding that heart disease in women often has a different pathophysiology from its presentation in men—particularly in younger adults.
2. **New diagnostic techniques**—some still experimental—are more effective than angiography for understanding the causes of IHD in women with chest pain in the absence of obstructive coronary artery disease.
3. **Understanding sex differences in symptoms** has led to earlier and better diagnosis of IHD in women.
4. **Rethinking the estrogen hypothesis** in light of large-scale trials of menopausal hormone therapy has challenged the (oversimplified) concept of a cardioprotective effect of estrogens.
5. **Gender analysis in risk factors and prevention** reveals that smoking has historically been more common among men than women; in some countries, such as Sweden and Iceland, however, smoking rates are now higher among women (Shafey et al., 2009). The harmful effects of tobacco smoke on atherosclerosis are greater in women than in men (Tremoli et al., 2010).

Osteoporosis Research in Men: Rethinking Standards and Reference Models

The Challenge

Men account for nearly a third of osteoporosis-related hip fractures in Europe and the US (Dhanwal et al., 2010). Nonetheless, osteoporosis is considered primarily a disease of postmenopausal women, and men are rarely evaluated or treated for it (Khosla et al., 2008).

Method: Rethinking Standards and Reference Models

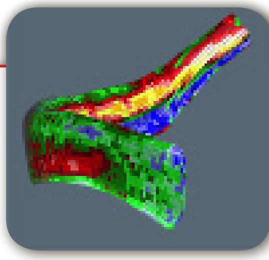
Research in many fields—for example, heart disease—has relied on reference models that treat men as the norm. Women are often studied as deviations from that norm. In the case of osteoporosis, however, diagnostic models have been developed for women using bone mineral density (BMD) norms of healthy young white women, and criteria to identify risk in men are not well established. Researchers are improving these reference models and opening new areas of research by considering disease progression in both women and men, and by evaluating risk using sex-specific reference models.

Gendered Innovations:

1. **Establishing Male Reference Populations.** By 1997, evaluation of men's bone quality was based on BMD norms of healthy young men rather than healthy young women (Looker, 1997). More work needs to be done to redefine diagnostic cutoffs for both women and men (Binkley et al., 2010).
2. **Creating New Diagnostics Based on Secondary Contributors to Osteoporosis and Metabolic Bone Disorders (SECOBs).** Researchers have identified medical conditions (such as hypogonadism and hypercalciuria) and treatments (such as chemotherapeutics and anticonvulsants) that correlate with osteoporotic fracture, especially in men. New diagnostics take SECOBs into account—along with variables such as BMD, sex, and lifestyle. Accounting for these factors improves diagnosis in both women and men.

TRANSPORT

Human Thorax Model: Rethinking Standards and Reference Models



This case study examines the "Development of a Finite Element Model of the Human Thorax and Upper Extremities" (THOMO) project, funded by EU FP7. We identify Gendered Innovations, methods of sex and gender analysis, and points of potential "value added."

The Challenge

Biofidelic models are critical tools in improving automobile occupant safety. They are used by engineers, manufacturers, and governmental agencies. The HUman MOdel for Safety (HUMOS-1), funded under the Fourth EC Framework Programme (FP4) from 1997 to 2000, was based on the study of a single male cadaver, representing "a 50th percentile seated man" (Pajon et al., 2002). HUMOS-2, funded under the EU FP5 from 2002 to 2006, collected anthropometric data from humans of the 5th, 50th, and 95th percentiles of overall weight, which is more inclusive of lighter people (mostly women) and heavier people (mostly men) (Dupont-Kerlan et al., 2006). Biofidelic models are often developed first for the 50th percentile man, excluding people who are significantly smaller or larger.

Method: Rethinking Standards and Reference Models

Models of the human body have long been based on the anthropometry of 50th percentile European and North American men (see Case Study: Pregnant Crash Test Dummies). Researchers are rethinking this standard and studying a wider range of women's and men's bodies in order to produce more advanced and representative human body models.

Gendered Innovations:

1. **Modeling Women's and Men's Thoraxes**. THOMO researchers are developing a model of the human thorax applicable to the **majority of women and men.**
2. **Consistent Biomechanical Testing** across Female and Male Thoraxes.

Potential Value Added to Future Research through the Application of Gendered Innovations Methods:

1. **Studying the Effects of Age and Menopausal Status** on Thoracic Bone Architecture.
2. **Including Geographically Diverse Populations.**
3. **Modeling Breast Tissue.**

Information for Air Travelers: Participatory Research and Design

This case study examines the "Interconnectivity through Infoconnectivity" (IC-IC) project, funded by EU FP7. We summarize the IC-IC project and identify points of potential "value added" through the future application of gendered innovation methods.

Interconnectivity through Infoconnectivity

Air travelers may have unmet needs for information when navigating unfamiliar airports. These needs arise from lack of standardized timetables and inconsistencies in ticket category types, pictograms, names for destinations, among other things (Bonsall et al., 2011).

IC-IC aims to produce an ICS (InfoConnectivity System) to optimize air travelers' access to information. The ICS is to be piloted at four large international airports: Amsterdam (Schiphol), Frankfurt, Paris (Charles de Gaulle), and Vienna. IC-IC seeks to make travel faster and more efficient, primarily by easing transfers between public transport (road, rail, etc.) and air travel. IC-IC also seeks to improve accessibility for the elderly and for travelers speaking different languages (CORDIS, 2012).

Potential Value Added to Future Research through the Application of Gendered Innovation Methods:

1. **Researching the needs of caregivers and available airport infrastructure.**
2. **Providing information to support traveling caregivers and their dependents.**

Pregnant Crash Test Dummies: Rethinking Standards and Reference Models

The Challenge

Conventional seatbelts do not fit pregnant women properly, and motor vehicle crashes are the leading cause of fetal death related to maternal trauma (Weiss et al., 2001). Even a relatively minor crash at 56km/h (35 mph) can cause harm. With more than 13 million women in the European Union and United States pregnant each year, the use of seatbelts during pregnancy is a serious safety concern (Eurostat, 2011; Finer et al., 2011).

Method: Rethinking Standards and Reference Models

The male body is often defined as the norm and used as the primary object of study. In this case, crash test dummies were first developed to model the US 50th percentile man (taken as the norm). This choice meant that other segments of the population were left out of the "discovery" phase in design. Inattention to humans of different sizes and shapes may result in unintended harm.

Gendered Innovations:

1. **Taking both women and men as the norm** may expand creativity in science and technology. Devices designed for broad populations will enhance safety.
2. **Analyzing sex has led to the development of pregnant crash dummies and computer simulations.**

Public Transportation: Rethinking Concepts and Theories

The Challenge

Categories used in transportation surveys—and, hence, the way statistics are gathered and analyzed—may not properly account for caring work. Public transport systems are typically designed around the needs of commuters (people traveling between their homes and places of paid employment). The mobility associated with caring work, including childcare and elder care, has typically not figured into transportation design.

Method: Rethinking Concepts and Theories

The innovative concept "mobility of care" provides a perspective for "recognizing and revaluing care work" (Sánchez de Madariaga, 2009). Incorporating "caring work" into user surveys helps to identify the significant number of trips that women and men make for this purpose. Understanding gender differences in public transportation is important for understanding climate change and planning efficient housing and neighborhoods.

Gendered Innovations:

1. **Adding the concept, "mobility of care," to data collection variables** may render public transportation more responsive to users' needs.
2. **Understanding gender differences in travel** has led to the concept of "trip chaining," with ramifications for the design of public transport systems.
3. **Gathering data disaggregated by sex and other factors intersecting with sex and gender** (such as income, family status, etc.) improves transportation research and policy.

METHODS OF SEX & GENDER ANALYSIS

Sex and gender can influence all stages of research, from strategic considerations for establishing priorities and building theory to more routine tasks of formulating questions, designing methods, and interpreting data. Many pitfalls can be avoided—and new ideas or opportunities identified—by designing sex and gender analysis into research from the start. Sex and gender analysis work together with other methodologies in a field to provide filters for bias and contribute to excellence in science and technology.

The Gendered Innovations website presents state-of-the-art methods of sex and gender analysis. As with any set of methods, new ones will be fashioned and others discarded as circumstances change. The value of their implementation depends on the creativity of the research team. There is no recipe that can simply be plugged into research or development processes. Researchers will want to consider all methods and think creatively about how these methods can enhance their research. Methods are applied in Case Studies.

Sex and gender analysis is integrated into each step of the research process (Methods are detailed in Annex C):

Rethinking Research Priorities and Outcomes

Rethinking Concepts and Theories

Formulating Research Questions

Analyzing Sex

Analyzing Gender

Analyzing How Sex and Gender Interact

Analyzing Factors Intersecting with Sex and Gender

Engineering Innovation Processes

Designing Health & Biomedical Research

Participatory Research and Design

Rethinking Standards and Reference Models

Rethinking Language and Visual Representation

CHECKLISTS

Checklists are intended for project directors, researchers, grant writers, and evaluators. Checklists provide stepwise procedures for incorporating sex and gender analysis into research and engineering, as a basis for developing Gendered Innovations. The checklists complement the Methods of Sex & Gender Analysis and should be read in conjunction with them (Checklists are fully detailed on the Gendered Innovations website).

Engineering

Health & Medicine

Tissues & Cells

Urban Planning & Design

CONCLUSIONS: NEXT STEPS?

Innovation has been placed at the heart of the Europe 2020 strategy. Gendered Innovations in science, medicine, engineering, and environment employ sex and gender analysis as a resource to stimulate creativity, new ideas, new services and new technologies, and by doing so enhance the lives of women and men around the world.

Designing sex and gender analysis into research and innovation is one crucial component contributing to world-class science and technology. The European Union has prioritized gender in Horizon 2020. Article 15 promotes "gender equality and the gender dimension in research and innovation content." Further, the European Research Area (ERA) partnership for excellence and growth encourages "gender equality and gender mainstreaming in research" to end the "waste of talent" by encouraging highly skilled women to pursue careers in science or technology. The ERA also seeks to capitalize on the "diversity of views and approaches" that fosters excellence in research.

As the case studies developed in the Gendered Innovations project demonstrate, integrating sex and gender analysis into research sparks creativity by offering new perspectives, posing new questions, and opening new areas to research. Sex and gender analysis enhances excellence in research. It adds value to society and business by making research responsive to a broad and diverse user base. Integrating the gender dimension into the concept of the Innovation Union will help to create more inclusive innovation processes. In supporting the Gendered Innovations project, the European Commission has developed a powerful tool for integrating gender analysis into research.

What are the important next steps? Next steps involve researchers, policy makers, institutional leadership, and industry.

1. Researchers. Realizing the full potential of Gendered Innovations in the next decade will require that this expertise be brought into the research process, either by scientists and engineers learning the methods of sex and gender analysis relevant to their work, or by experts in gender analysis joining a research team. The current generation of researchers needs to learn how to exploit the creative power of sex and gender analysis in their research design.

2. Granting Agencies.

a. Proposal Requirements. The European Commission is currently the global leader in policy in the area of gender analysis. The European Commission implemented its cutting-edge policy in 2003, asking that applicants specify whether, and in what sense, sex and gender are relevant in the objectives and methods of their projects. The European Union can retain its leadership in Horizon 2020 by again asking that applicants explain how sex and gender analysis is relevant to the concepts and objectives of the proposed research. Researchers might also demonstrate that sex and gender are not relevant to a particular project. It is important, however, that the issue is explored and becomes an integral part of the proposals to be evaluated.

b. **Proposal Evaluation.** Evaluators should to be trained to carry out gender reviews of proposals, using a template with a checklist, particularly for those dealing with humans as either subjects or users.

3. Research Institutions. Hiring and promotion committees can evaluate researchers and educators on their success in implementing gender analysis. Knowledge and use of methods of sex and gender analysis can be one factor taken into consideration in hiring and promotion decisions.

4. Editors of Peer-Reviewed Journals. Editorial boards can require sophisticated use of sex and gender methodology when selecting papers for publication. A number of journals do so for instance, *Nature,* the *Journal of the American College of Cardiology*, and the *Canadian Medical Association Journal*. Journals should also enforce consistent use of keywords such as "sex" and "gender" to facilitate meta-analysis (see Annex A—Definition of Terms). A list of journal policies can be found on the Gendered Innovations website.

5. Industry. Inventions that incorporate the smartest aspects of gender can open new markets and enable innovation in products, processes, services, or infrastructures. Gender expertise—whether developed internally or brought in by consultants—can help industry identify new markets, develop technologies, and bring new ideas to market. Products that meet the needs of complex and diverse user groups enhance global competitiveness and sustainability.

6. The Next Generation. Sex and gender analysis should be integrated into high school and university curricula, including basic science, medicine, and engineering courses. Textbooks should be revised to integrate sex and gender results and methods.

The Expert Group "Innovation through Gender" has explored how employing methods of sex and gender analysis produces excellence in research that also meets the needs of both women and men. We invite researchers, policy makers, journal editors, industry leaders, and students (among many others) to join us in this endeavor.

ANNEX A: Definition of Terms Used in Gendered Innovations

Sex and Gender are Distinct Terms

It is essential to grasp the sex/gender distinction and to use the relevant terms accurately. For example:

Sex is a biological quality.
Gender is a socio-cultural process.

1. A conference on "Sex Differences in Pain" would address biological determinants of pain perception between women and men. A conference on "Gender Differences in Pain" would address socio-cultural assumptions about how women and men experience pain differently (Fishman et al., 1999).
2. An engineering study on "Sex Differences in Drivers' Needs" would examine biological differences between women and men that are important in automotive design (for example, women's potential to be pregnant should be taken into account in designing seatbelts, and differences between women's and men's overall weight may need to be considered in designing airbags) (Jain, 2006). In contrast, a study on "Gender Differences in Drivers' Needs" would examine how women and men use vehicles differently because of gender relations—for example, because women typically perform more childcare, they are more likely than men to transport children in their vehicles (Temm, 2008).

Sex

"Sex" is a biological quality or classification of sexually-reproducing organisms, generally female or male, according to functions that derive from the chromosomal complement, reproductive organs, or specific hormones or environmental factors that affect the expression of phenotypic traits that are strongly associated with females or males within a given species. Hormonal (and environmental) effects, which may be organizational (differentiating) and essentially permanent, or activational, thus possibly reversible, are strongly influenced by the genetic make-up of the individual (Wallen, 2009). Therefore, a range of traits are expressed within each sex, with

Problems to Avoid when Analyzing Sex
Problems can arise if researchers assume that :

- all females (or all males) are the same.
- females and males are different.
- apparent differences between women and men are solely biological.
- apparent differences between women and men hold across cultures.

considerable overlap of “female” and “male” phenotypic traits, especially for “secondary sex characteristics.” Sex may be defined according to:

1. **Genetics:** chromosomal make-up (female/male), such as ZW/ZZ (birds and some insects), XX/XO (insects), and XX/XY (most mammals). In mammals the sex-determining region of the Y chromosome, SRY, plays the greatest role in sex differentiation, but because of other transcription factors, such as DAX1 and FOXL2 in females and SOX9 in males, or translocation of the SRY to the X chromosome or an autosome, females and males may have karyotypes other than 46,XX and 46,XY, respectively (see Case Study: The Genetics of Sex Determination). Regardless of karyotype, the presence of sex-determining genes means that every nucleated human cell has “sex.” (Note: many species have non-genetic sex-determination systems—see below.)
2. **Gametes:** germ cells. In species that produce two morphologically distinct types of gametes with each individual producing only one type, the egg-sperm distinction is the basis for distinguishing between females and males, respectively.
3. **Morphology:** physical traits that differentiate female and male phenotypes.
   a. **Primary sex characteristics** in humans and many other animals include:
      i. **internal reproductive organs and genitalia**, which derive from “bipotential” organs (e.g., “indifferent gonads” that become ovaries or testes) and dual structures. Usually, one structure is maintained and the other regressed. For example, human embryos have both mesonephric and paramesonephric ducts. The former become Müllerian ducts (and form the fallopian tubes, uterus, and proximal vagina) in females, but regress in males. The latter become Wolffian ducts (and form the seminal vesicles, epididymis, and ductus deferens) in males, but regress in females.
      ii. **external genitalia**, which generally differentiate toward one of two basic forms: distal vagina, labia, and clitoris in females; and scrotum and penis in males; nevertheless, external genitalia may not reflect karyotypical or internal genital sex (Fausto-Sterling, 2000).
      iii. **sexually dimorphic prenatal neural structures.** Many morphological and functional brain dimorphisms arise during late gestational and neonatal periods. They may be due to differentiating effects of fetal hormones and other sex-biased regulatory mechanisms, including genetic and environmental factors (McCarthy et al., 2011; Jazin et al., 2010).
      iv. **other sexually dimorphic tissues under continuing study.** As research on “sex” continues to expand beyond reproduction and neuroscience, sexual dimorphism in other fetal structures will receive increasing attention.
   b. **Secondary sex characteristics** are phenotypic traits strongly associated with females or males that become prominent at puberty when the ovaries and testes produce much higher levels of estrogens and androgens, respectively. Often referred to as “gonadal hormones” (though also produced by the adrenal gland and metabolized in many body tissues) or “sex hormones” (though other hormones and genetic factors influence female and male phenotypic traits and “sex hormones” have roles unrelated to sex differentiation), both classes of hormones have important biologic effects in both sexes. For example, estrogens are critical to skeletal development in both sexes, and androgens are responsible for pubic and axillary hair growth at puberty in both sexes.

Examples of secondary sex characteristics in humans include shorter stature and wider pelvis, breast development, and more fat in the thighs and buttocks in women and broader shoulders, greater muscle mass, more facial and other body hair, and "male pattern" baldness in men. As noted above, these traits vary within each sex and ranges overlap. For instance, many women are taller than many men and some women are stronger than many men—see Method: Analyzing Sex (below).

These traits can also be promoted by exogenous hormones. For instance, muscle mass and facial hair will increase in women who take androgens, and breasts and other "female" traits will develop in men who take estrogens.

Non-genetic sex determination systems are known in many species (Gilbert, 2010). These are diverse and include:

- **Thermal sex determination:** In all crocodilians, most turtles, and some other reptiles, sex determination is partially or entirely temperature-dependent. In certain species, sex is genetically determined within a temperature range but environmentally determined outside that range.
- **Age-based sex determination:** In some species, such as the slipper snail *Crepidula fornicata*, all young individuals are male, but some later change to female, depending on their position in a mound of snails.
- **Social sex determination:** In many fish species, sex is determined through social interactions with other members of a school. In the echiuroid worm *Bonellia viridis*, sex is determined by physical environment: Larvae that land on the ocean floor develop as females (~10 cm. long), whereas larvae that are engulfed by a mature female through her proboscis develop as males (~2 mm. long) and live symbiotically.

Intersex may be defined as "atypical anatomy," a combination of what are considered male-typical and female-typical chromosomal, gonadal, and genital characteristics (Karkazis, 2008; Kessler et al., 1985).

Gender

Definition: Gender—a socio-cultural process—refers to cultural and social attitudes that together shape and sanction "feminine" and "masculine" behaviours, products, technologies, environments, and knowledges.

Note : Several European languages do not have a word for "gender". It is important to devise a language-specific word or use the English correctly.

Background: The term "gender" was introduced in the late 1960s to reject biological determinism that links biology with rigid sex roles and expectations. "Gender" is used to distinguish socio-cultural factors shaping behaviours and attitudes from biological factors related to sex (see Terms: Sex, and Sex and Gender are Distinct Terms). Gendered behaviours and attitudes are *learned*; they are neither fixed nor universal. Gender norms, gender relations, and gender identities are constantly in flux. They change by historical era, culture, and place, such as the 1950s versus the 2010s, Spain versus Germany, urban versus rural areas. Gender also

Problems to Avoid when Analyzing Gender

Problems can arise if researchers assume that:

- all women as a group or all men as a group (their attitudes, preferences, needs, behaviours, and knowledge) are the same.
- women and men are different.
- observed differences between women and men are solely biological in origin.
- observed differences between women and men hold across cultures.

differs by specific social contexts, for example at work versus at home. Gender identities interact with other identities, such as ethnicity or class (see Method: Analyzing Factors Interacting with Sex and Gender).

How Gender Functions:

Humans function in large and complex societies through learned behaviours. The ways we speak, our mannerisms, the things we use, and our behaviours all signal who we are and establish rules for interaction. Gender is one aspect of these sets of behaviours and attitudes. As such, gender can be an important aspect of research and design (see Methods: Analyzing Gender, Rethinking Research Priorities and Outcomes, Formulating Research Questions, Rethinking Concepts and Theories, Engineering Innovation Processes, Designing Health & Biomedical Research, Rethinking Standards and Reference Models, and Rethinking Language and Visual Representations).

1. Gender Norms refer to *attitudes* about what behaviours, preferences, products, professions, or knowledge is appropriate for women and men. Gender norms influence the development of products and technologies (see Case Studies: Exploring Markets for Assistive Technologies for the Elderly, Machine Translation, Making Machines Talk, Video Games, among others):

- Gender norms draw upon and reinforce gender stereotypes, which are widely held, idealized beliefs about women and men, femininities and masculinities.
- Gender norms and behaviours are produced through social institutions (such as families, schools, workplaces, laboratories, universities, or boardrooms) and wider cultural products (such as textbooks, literature, film, and video games—see Method: Rethinking Language and Visual Representations).

2. Gender Relations refer to empirical observations of the *actual* roles women and men take on and how they interact in a particular culture or social context—such as in the home, in the lab, or on the design team.

- Social divisions of labor are an important aspect of gender relations where women and men are concentrated in different types of (paid or unpaid) activities. One consequence of such gender segregation is that particular occupations or disciplines become "marked" symbolically with the (presumed) gender identity of the numerically dominant group: for example, nursing is seen as a "feminine" profession, engineering as "masculine" (Faulkner, 2009).
- Women and men who work in highly segregated roles acquire different kinds of knowledge or expertise, which can sometimes be usefully accessed for gendered innovations (see Method: Participatory Research and Design; see also Case Study: Water Infrastructure).
- Gender relations can also become embodied in products or built environments, such as transportation systems (see Method: Rethinking Language and Visual Representations; see also Case Study: Public Transportation).

3. Gender Identities refer to how individuals and groups perceive and present themselves, and how they are perceived by others (Schiebinger, 1999). Gender identities are context-specific. Any individual engages in multiple femininities and masculinities (consciously or unconsciously), depending on the particular context. For example, a man directing a lab meeting may use masculine-identified leadership skills, but he may employ more feminine-identified qualities when helping his child with math. Note that:

- **Gender identities** can influence research (see Method: Analyzing Gender).
- **Transsexual, Transgender,** and **Gender-Nonconforming** are terms that describe "expression of gender characteristics, including identities that are not stereotypically associated with one's assigned sex at birth." These forms of expression are common and are not considered inherently pathological (WPATH, 2011). Nevertheless, prejudice against gender-nonconforming people can cause harm (Meyer, 2003).
- **Gender Dysphoria** or **Gender Identity Disorder (GID)** is "discomfort or distress that is caused by a discrepancy between a person's gender identity and that person's sex assigned at birth (and the associated gender role and/or primary and secondary sex characteristics)" (WPATH, 2011). It is experienced by a subset of gender-nonconforming people. GID is classified as a medical disorder by major organizations, including the World Health Organization (WHO) and the American Psychiatric Association (APA) (APA, 2000; WHO, 1990). Available treatments include hormonal and surgical interventions (WPATH, 2011).

Interactions between Sex and Gender

"Sex" and "gender" are analytically distinct but not independent terms. They should be clearly and explicitly defined when reporting research results. Sex and gender also interact in important and complex ways (see Method: Analyzing how Sex and Gender Interact). Rarely does an observed difference between men and women involve only sex and not gender, and rarely does gender operate outside of the context of sex. The precise nature of their interaction will vary depending on the research question and on other factors, such as socioeconomic status or geographic location, interacting with sex and gender (see Method: Analyzing Factors Intersecting with Sex and Gender).

1. **Biological sex influences socio-cultural gender.**

   Example (Engineering): In some cultures, differences in rates of education between boys and girls are influenced by biological sex differences. For example, lack of good water infrastructure can discourage girls from attending school. Menstruation increases girls' need for clean latrines and privacy at school. In Uganda, for example, dropout rates for girls rise dramatically around age 12-13, consistent with menarche (see Case Study: Water Infrastructure).

2. **Socio-cultural gendered behaviours influence sex differences in biology.**

   Example (Health & Medicine): Gender roles interact with sex in determining osteoporosis risk. Sex differences in osteoporosis incidence, long attributed to biological sex, may result in part from gendered behaviours that influence diet, sun exposure, and weight-bearing exercise (see Case Study: Osteoporosis Research in Men).

Not Considering Sex Differences as a Problem

The male body has long been taken as the norm (see Method: Standards and Reference Models). Female bodies have often been studied as they deviate from that norm. Often, results from single-sex studies are generalized beyond the sex studied.

Research and design should be set up to identify significant sex differences.

> **Example (Science/Medicine):** Diagnostic models for osteoporosis have been traditionally been developed for women, and criteria to identify risk in men are not well established. New research is considering disease progression in both women and men by evaluating risk using sex-specific reference models (see Case Study: Osteoporosis Research in Men).
>
> **Example (Engineering):** Safety devices, such as safety belts, were first developed to fit the 50th percentile man (taken as the norm). Inattention to humans of different sizes and shapes may result in unintended harm. Conventional seatbelts do not properly fit pregnant women, for example, and vehicle crashes are a leading cause of accidental fetal death due to maternal trauma (see Case Study: Pregnant Crash Test Dummies).

Overemphasizing Sex Differences as a Problem

Overemphasizing sex differences can lead to error. This may happen:

1. **When sex differences are asserted without sufficient evidence or documentation.** Statistically sound, peer-reviewed data are needed to support scientific claims of sex differences. Researchers may assert or suggest sex differences even in the absence of sufficient data, or sufficient data analysis. The bias against reporting negative or null results means that findings of sex difference are reported more often than findings of no sex difference (IOM, 2012).

   Example (Disease Genetics): Many diseases show differences in prevalence according to both sex and other genetic traits. For example, systemic lupus is an autoimmune disease with higher prevalence in women than men (i.e., sex is a risk factor) and higher prevalence in people with specific forms of human leukocyte antigen genes (i.e., genetic makeup is a risk factor) (Martens et al., 2009). As a result, researchers are interested in determining how sex and other genetic traits interact in determining risk—if a particular genetic trait is a risk factor only for women or only for men, this information would be useful in disease screening. A review of peer-reviewed papers reporting “sex-related differences in genetic associations” found that “most claims were insufficiently documented or spurious.” Problems included lack of control groups, comparing dissimilar cohorts of women and men (such as cohorts of different ages), and many others (Patsopoulos et al., 2007).

2. **When differences between women and men are improperly attributed to sex.** Researchers may assume that differences between women and men are due to sex when in fact other factors—such as gender roles or socioeconomic status—come into play. Overemphasizing sex differences can lead, and historically has led, to stereotyping women

and men. The US National Institute of Medicine has noted that "Historically, studies on race, ethnicity, age, nationality, religion, and sex have sometimes led to discriminatory practices." The committee recommended that these practices be understood so that they are not repeated (Pardue et al., 2001).

Example (Software Design): Video game firms have produced "pink" and "blue" games according to beliefs about fundamental differences in women's and men's interests and skills—interests that are sometimes seen as innate. Blue games typically focus on combat, and pink games focus on fashion. Recent research shows that gender norms about the appropriateness of gaming influence women's and men's gaming patterns. These norms are changing, and some of the most popular modern games have similar proportions of women and men players. Designing for a broad audience is often a more successful strategy than creating games for players of one sex (Faulkner et al., 2007) (see Case Study: Video Games).

3. **When sex is emphasized to the exclusion of other important variables.**

   Example (Bioengineering and Medicine): Is a female-specific knee prosthesis necessary? Overall, there is a lack of evidence that female-specific prostheses improve women's total knee arthroplasty outcomes. Sex influences both height and knee morphology, but evidence suggests that the choice of a knee prosthesis is better based on the continuous variable of height than the binary variable of sex. Overemphasizing sex differences in knee prostheses may harm both men and women—the "female" knee may be a good physiological fit for some men and a poor fit for some women (see Case Study: De-Gendering the Knee).

Women & Men

The terms "men" and "women" refer exclusively to humans. Humans are shaped by both biological sex and socio-cultural gender (see Method: Analyzing how Sex and Gender Interact). Referring to women and men as "female" and "male" captures only the biological aspects; hence it is preferable to say "women scientists" or "men scientists."

When thinking about women and men, it is important to analyze two types of difference:

1. **Differences between groups of women and men.** "Women" and "men" can be important social and political categories. For example, all women—regardless of social class—were prohibited from studying at European and US universities until the late nineteenth century. Until recently, all men as a group were subject to the draft for US military duty.
2. **Differences within groups.** There are significant differences *among* women and differences *among* men. An important question to ask is: Which women? Or which men? Women as a group differ by socioeconomic status, religion, race, age, and other social categories (see Method: Analyzing Factors Intersecting with Sex and Gender). These differences may be greater than those between women and men. For example, osteoporotic fractures are more common in women than age-matched men, and many forms of heart disease are more common in men than age-matched women, but for both diseases, age is a far better predictor of incidence than is sex (see Case Studies: Heart Disease in Women and Osteoporosis Research in Men).

Female & Male

"Female" and "male" describe biological sex—in humans, non-human animals, and other organisms. "Females" and "males" should be used only when the subject matter in question is solely biological sex.

- "Women" and "men" should be used when referring to humans where both biology and culture are concerned, such as "women engineers" or "men engineers."
- "Female" and "male" should be used when referring specifically to sex (a biological characteristic).
- "Femininities" and "masculinities" should be used when discussing gender traits (socio-cultural characteristics).

Femininities & Masculinities

"Femininities" and "masculinities" describe gender identities (see Term: Gender). They describe socio-cultural categories in everyday language; these terms are used differently in biology (see below). Because femininities and masculinities are gender identities, they are shaped by socio-cultural processes, not biology (and should not be essentialized). Femininities and masculinities are plural and dynamic; they change with culture and with individuals.

Points to keep in mind:

- In everyday language, femininities and masculinities do not map onto biological sex. In any one culture, certain behaviours or practices may be widely recognized as "feminine" or "masculine," irrespective of whether they are adopted by women or by men. Femininities and masculinities are not descriptors of sexual orientation.
- Femininities and masculinities are plural—there are many forms of femininity and many forms of masculinity. What gets defined as feminine or masculine differs by region, religion, class, national culture, and other social factors. How femininities and masculinities are valued differs culturally.
- Any one person—woman or man—engages in many forms of femininity and masculinity, which she or he adopts (consciously or unconsciously) depending on context, the expectations of others, the life stage, and so forth. A man can engage in what are often stereotyped as "feminine" activities, such as caring for a sick parent.
- Cultural notions of "feminine" and "masculine" behaviour are shaped in part by observations about what women and men do. This kind of "gender marking" tends to discourage women or men from entering "gender-inauthentic" occupations (Faulkner, 2009).
- Femininities and masculinities are learned. Messages about "feminine" and "masculine" behaviours are embedded in advertising, media, news, educational materials, and so forth. These messages are present in a range of environments, from the home to the workplace to public spaces.

Note on biology: Although the terms "feminine" and "masculine" are gender terms (socio-cultural categories) in everyday usage, they carry different meanings in biology. Masculinization refers to the development of male-specific morphology, such as the Wolffian ducts and male reproductive structures. Feminization refers to the development of female-specific morphology, such as the Müllerian ducts and female reproductive structures. In order to become a reproductively functioning female, for example, both feminization and demasculinization are required, and vice versa for males (Uhlenhaut et al., 2009).

Stereotypes

A stereotype is a widely held, simplified, and essentialist belief about a specific group. Groups are often stereotyped on the basis of sex, gender identity, race and ethnicity, nationality, age, socioeconomic status, language, and so forth. Stereotypes are deeply embedded within social institutions and wider culture. They are often evident even during the early stages of childhood, influencing and shaping how people interact with each other. For example, video game designers designed a game platform for girls in pink because that is what the parents (who purchase the game) perceived their girls wanted. The girls themselves preferred darker metallic colors (Rommes, 2006).

Gender stereotypes reflect normative notions of femininities and masculinities, women and men. Yet, like all aspects of gender, what constitutes stereotypical femininity or masculinity varies among cultures and over historical time. Gender stereotypes typically portray femininities and masculinities as binary opposites or dualisms, as, for example, between emotionality and rationality.

By oversimplifying their subject, stereotypes ignore both the complexity and the diversity found empirically when one examines *actual* people and their practices; by their very nature, stereotypes misrepresent the groups they seek to describe. Stereotypes often persist even when the statistical realities they were once based on change. For example, the stereotype of woman-the-homemaker has persisted even in countries where most women are in full-time paid employment.

For all these reasons, stereotypes are not a sound basis for making interpretations in the course of research or for making judgments about target users and customers. *Researchers and engineers must challenge stereotypes and look instead for more empirically sound bases for thinking about the groups they seek to research or develop technologies for.* Femininities and masculinities are dynamic and plural. Women, for example, have a wide variety of interests and skills. If a mobile phone is designed for a "stereotypical" woman, it will not appeal to women who do not fit the stereotype being promoted (Faulkner, 2004).

Avoiding Stereotypes

1. Find out about actual people and practices—across classes, regions, educational backgrounds, and so forth; do not make assumptions based on normative or stereotypical notions about women and men.
2. Consider both the structural and cultural mechanisms by which gender divisions and inequalities are often sustained. Observation-based methods are more likely to reveal important invisible dynamics than are interviews or surveys, not least because people's actual practices may differ from their accounts of themselves.

3. Seek to expose “mismatches” between gender norms, assumptions, or stereotypes and actual people or practices. Doing so can reveal fertile spaces for creative, gender-sensitive innovation—innovation capable of driving scientific and technological progress and at the same time improving gender equality.

Stereotype Threat

Stereotypes can adversely affect performance. “Stereotype threat”—the perceived threat of being reduced to the stereotype of the group with which one is identified—can lead capable individuals within a group to “conform” to their group’s negative stereotype. For example, when young women are reminded of their sex before taking a math test, by being asked to tick a “female” or “male” box, they tend to score lower than when there is no F/M box to tick (Steele, 1997). Similarly, white men engineering students’ performance on a math test decreases if these men are told that Asian engineering students are taking the same test (Page, 2007).

Feminisms

Feminism advocates social, political, economic, and intellectual equality for women and men. Feminism defines a political perspective; it is distinct from sex or gender.

Feminism means very different things to different people. The many variants of feminism are associated with a variety of philosophical and political outlooks. Sue V. Rosser has distinguished at least ten different feminist approaches to science and technology (Rosser, 2008).

Many people in Europe, the US, and elsewhere practice feminism without self-identifying as “feminists.” The vast majority of Europeans and Americans are feminists, at least liberal feminists—that is to say, they support equality and professional opportunities for women. It is important to recognize that what is labeled “feminist” in one time and place becomes business as usual in another. It is a curious phenomenon that when feminist practices or points of view become widely accepted in science, medicine, engineering, or the culture more generally, they are no longer considered “feminist,” but simply “just” or “true.” The result is that the term “feminist” continues to refer to people and policies on the radical cutting edge (Schiebinger, 1999).

Here we present four broad feminist approaches. Although these approaches differ, they are not mutually exclusive, nor does one supersede any other. These approaches represent basic strategies guiding research, legislation, and policies.

1. **Liberal Feminism, or the Equality Approach**, has been the leading form of feminism in the US and much of Western Europe since English feminist Mary Wollstonecraft’s vigorous call for equality for women in her 1792 *Vindication of the Rights of Woman*. It has informed major legislation guaranteeing women equal rights, education, pay, and opportunity (in Europe the Amsterdam Treaty of 1999; in the US, the Equal Pay Act of 1963, Title IX of the Education Act Amendments of 1972, and the Equal Opportunity Employment Act of 1972). Liberal feminism has been criticized for not recognizing sex and gender

differences. It is often considered "assimilationist," meaning that women, and not society or culture, are required to change in order for women to succeed.

2. **Difference Feminism** represents a broad spectrum of feminisms that emphasize differences between women and men. This approach arose in the 1980s and 1990s in efforts to revalue qualities traditionally devalued as "feminine"—such as subjectivity, caring, feeling, or empathy. This approach identifies bias in science and technology by seeing what has been left out from feminine perspectives—sometimes expressed as "women's ways of knowing." Difference feminisms have been criticized as being essentialist. Difference feminism tends to romanticize traditional femininity and masculinity and to reinforce conventional stereotypes. This approach fails to take into account that women and men across classes and cultures hold many different perspectives and values.
3. **Co-Constructionism** analyzes how science/technology and gender mutually shape each other (Faulkner, 2001; Oudshoorn et al., 2004). Gender identities are produced simultaneously with science and technologies; neither precedes the other. Gender is understood to be material, discursive, and social; it permeates artifacts, culture, and social identities. Co-constructionism seeks to avoid both technological determinism (seeing technology as the prime driver of modernity) and gender essentialism (seeing gender characteristics as innate and unchangeable).
4. **Sex and Gender Analysis** enriches science, health & medicine, and engineering research by analyzing how sex and gender influence all phases of research, including setting priorities, making funding decisions, establishing project objectives and methods, gathering and analyzing data, evaluating results, developing patents, and transferring ideas to markets (Schiebinger et al., 2011). This approach prioritizes analysis (not prescription) to guide efforts to achieve gender equality. Simultaneously, this approach employs sex and gender analysis as a *resource* to stimulate creativity in science and technology, and by doing so enhance the lives of both women and men.

ANNEX B: Eight Full Case Studies

Reproduced here are eight case studies presented on the Gendered Innovations website (full citations can be found on the website). More case studies are available on the website.

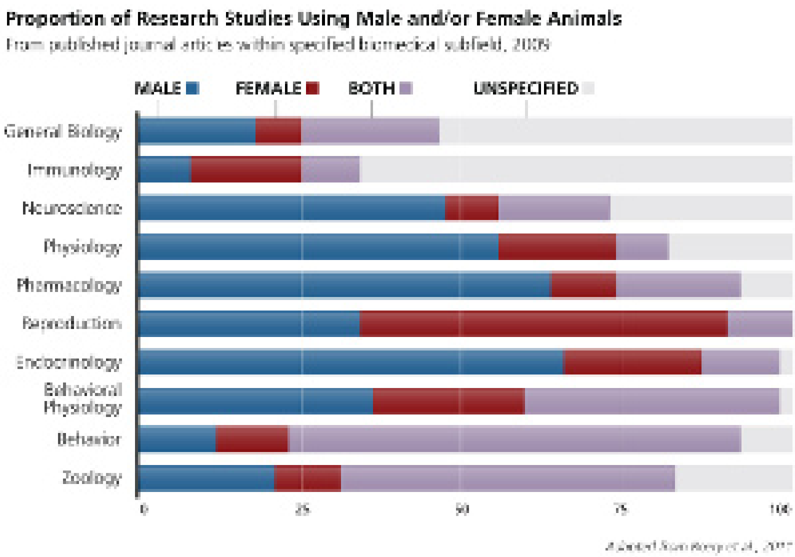
BASIC SCIENCE

Animal Research: Designing Health & Biomedical Research

The Challenge

Research using animals has been vital to Western science and medicine since its inception. Until the 1960s, however, the sex of animals used in research was rarely reported except in experiments related to reproduction. Even today, the sex of animal subjects is "omitted in 22–42% of articles in neuroscience, physiology, and interdisciplinary biology journals" (Beery et al., 2011).

Analysis of animal studies in which sex is reported shows that females are underrepresented in most subfields except reproductive biology and immunology—see chart below.



The Underrepresentation of Female Animals

Researchers may perform single-sex animal studies to reduce the cost of experiments or in hopes of lowering the variance of results (McCarthy et al., 2002). Single-sex experiments are the only option in studying sex-specific phenomena (ovarian cancer or prostate cancer, for instance) and can also be beneficial if one sex has been understudied or if there is strong evidence that sex does not influence outcome. The majority of single-sex animal experiments, however, do not fall into these categories. Female animals are underrepresented in studies of conditions that affect both sexes and are underrepresented in research where evidence suggests that sex influences outcome.

Researchers may avoid using female animals because hormone levels, which fluctuate throughout the estrous cycle, can interact with experimental outcomes (Becker et al., 2005; Wizemann et al., 2001). More rarely, researchers may avoid using male animals because, in some species and strains, inter-male aggression makes caging difficult (Gatewood et al., 2006). Female rodents may be preferred in toxicology studies because of their greater sensitivity to some toxins (European Commission, 2008).

Gendered Innovation 1: Studying Sex leads to New Treatments for Traumatic Brain Injury

Traumatic brain injury (TBI) is more common in men than in women both in Europe (where the leading cause is motor vehicle collisions) and in the United States (where the leading cause is firearm injuries; Tagliaferri et al., 2006; Wagner et al., 2000; Roof et al., 2000). New studies of TBI that include female animals have allowed sophisticated sex analysis and produced innovations in treatment for TBI patients (see Method).

Method: Analyzing Sex

Sex analysis begins when researchers use animals of both sexes in an experiment and analyze data to determine whether outcomes for females and males are different. In animal models of TBI, females consistently exhibit better outcomes than males—that is, females are the "most protected" sex and males are the "most affected." This difference holds across multiple species and a variety of inbred and outbred mouse strains (Hurn et al., 2005).

Once a sex difference is observed, further experiments can elucidate the mechanism of difference (Grove et al., 2010)—see Method below.

Method: Designing Studies in Biomedical Research

Determining the presence or absence of a sex difference requires consideration of the estrous cycles of female animals; if the estrous cycle is not considered, sex differences might exist but not be detected, as a result of averaging over the cycle (Stoffel et al., 2003). Mechanistic studies are also needed to definitively assess sex differences or lack thereof in animal experiments; for example, a particular drug or other intervention might produce the same effects in both sexes but act by different mechanisms (Liu et al., 2007). Furthermore, multiple sex-specific differences can have opposing effects and cancel each other out, preventing observation (Palaszynski et al., 2005).

If a sex difference is observed in an animal model, it is important to test for the contribution of sex:

1. **Sampling Female Animals at Different Points in the Estrous Cycle.** In reproductively competent animals, a powerful study design involves monitoring female animals' estrous cycles. A basic experimental design might involve ten groups of mice: two groups of males (experimental and control) and eight groups of females (experimental and control for each of the four days of the estrous cycle). A simpler option is to include females representing only two parts of the cycle, typically estrus and diestrus (Becker et al., 2005). Furthermore, as some mammals exhibit synchrony of ovulation, females should be housed to prevent close contact between mice ovulating on different days (Meziane et al., 2007).

   In animal models of TBI, estrous cycle appears to have little influence on outcome (Wagner et al., 2004). But estrous cycle effects have been important in studies of immune function (see Gendered Innovation 2 below).

2. **Sampling Female Animals during Pregnancy or Pseudopregnancy.** TBI researchers who sampled male rats, normally-cycling female rats, and pseudopregnant female rats found that edema was most severe in males, less severe in normally cycling females, and least severe in pseudopregnant females (Roof et al., 1993). Progesterone levels are known to be lowest in males, higher in normally cycling females, and highest in pregnant or pseudopregnant females, which suggested to researchers that progesterone may protect against edema (Meffre et al., 2007).

3. **Artificially Manipulating Hormones.**

   In animal models of TBI, ovariectomy reduces the survival advantage that intact females have over males. Injection of progesterone partially restores this advantage in ovariectomized females and also improves survival in males (Bayir et al., 2004).

Researchers used evidence from animal models of TBI—obtained through analyzing sex and sampling female animals in different hormonal states—to devise an experimental treatment for humans. In double-blind clinical studies, patients who received progesterone shortly after emergency treatment for TBI had lower mortality and showed better recovery of neurological function than control patients with similar injury, and progesterone was well-tolerated (Xiao et al., 2008; Wright et al., 2007). More research is needed to:

- Evaluate risks and benefits of progesterone treatment according to patient characteristics (such as sex and age) and injury characteristics.
- Elucidate the mechanisms by which progesterone protects against brain damage in TBI.

Gendered Innovation 2: Sampling with Attention to Estrous Cycles and Menopause Advances Basic Knowledge of the Immune System

By including female mice in experiments, scientists discovered that sex hormones are important to immune system function. When female mice were exposed to antigens and then sampled during diestrus or estrus, their immune responses in the spleen were similar to those seen in males. But when female mice were sampled during proestrus or metestrus, their antibody counts were more than triple that of males (Krzych et al., 1978). By correlating these differences with progesterone and estrogen concentrations (which also vary throughout the estrous cycle), it was possible to uncover the influence of sex hormones on immune function (Bergman et al., 1992).

Animal models of menopause—which are still in development (see Next Steps below)—have shown that immunological changes accompany this hormonal transition. When mice are ovariectomized and undergo "acute menopause," they exhibit "reduced lymphocyte chemotaxis, mitogen-induced T cell proliferation responses, and [Interleukin-2] production" (Marriott et al., 2006).

An understanding of hormones and immune function is relevant to treating numerous diseases, including autoimmune diseases and HIV infection. For example, animal models have been used to investigate why HIV viral load tends to increase more rapidly in men than in women (Meier et al., 2009).

Gendered Innovation 3: Strengthening Environmental Health Standards

In addition to their use in basic research and preclinical testing, animal models are integral to environmental monitoring and evaluating the toxicity of chemicals. The European Commission's Institute for Health and Consumer Protection (IHCP) and the US National Toxicology Program (NTP) have analyzed reference models to improve environmental standards (see Method).

Method: Rethinking Standards and Reference Models

Consideration of sex in toxicology reference models is important: Both model organisms and humans show sex differences in sensitivity to certain toxins, and in some cases, a compound may have qualitatively different effects in females and males—particularly if the compound is an endocrine disruptor (see Case Study: Environmental Chemicals).

The IHCP uses a "sex-linked recessive lethal test" in drosophila as a model of mutation in order to screen chemicals for mutagenic activity (European Commission, 2008).

Standards and Reference Models in the EU

The European Commission's IHCP has strong requirements for sex analysis and sampling (European Commission, 2008):

1. **Inclusion of Female and Male Animals.** For example, in inhalation toxicity testing, researchers are instructed to use equal numbers of females and males at each concentration level. In other tests, the sex more sensitive to a particular toxin, generally females, is preferred.
2. **Reporting the Sex of Study Subjects.** Regardless of whether an experiment is single-sex or mixed-sex, the IHCP requires reporting "number, age, and sex of animals."
3. **Sampling Pregnant Females to Detect Developmental Toxicity.** This protocol allows researchers to gather "information concerning the effects of prenatal exposure on the pregnant test animal and on the developing organism in utero."

Standards and Reference Models in the US

The US National Toxicology Program (NTP) requires sex analysis in all routine animal toxicity studies (NTP, 2006), which must:

1. **Report the Sex of Study Subjects.** NTP states that "data are to be tabulated and organized by species, sex, and treatment group."
2. **Analyze Results by Sex and Report Null Findings.** All analyses performed by the NTP note the presence, absence, and statistical significance of sex differences.
3. **Analyze Factors Intersecting with Sex.** All analyses are to be controlled for weight so that weight differences are not misreported as sex differences or vice versa.

Conclusions

Gendered Innovations:

1. **Physiology and Pathophysiology:** Including female animals in experimental studies led to new knowledge about traumatic brain injury, resulting in new therapeutics. Sampling with regard to sex and hormonal state has also produced knowledge about hormonal regulation of the immune system, relevant to the treatment of autoimmune diseases and

infections. This information is now being applied to development of treatment dosing for vaccines (Klein et al., 2010; World Health Organization, 2010).

2. **Regulatory Policy:** Analyzing sex has become a critical part of both EU and US efforts to understand, prevent, and control environmental pollution.

Next Steps

A. Future research needs:

1. **Analyzing Sex at the Tissue and Cellular Level.** Sex analysis in basic research has occurred primarily in animal studies and has centered on hormonally mediated sex differences. Sex is rarely analyzed or even reported in studies involving cultured cells or extracted tissues. A study of articles in high-impact, peer-reviewed cardiovascular disease journals showed that only 20-28% of articles describing research on new cell lines stated the sex of cells used. Of the minority of studies that did report sex, 69% used male cells only (Taylor et al., 2011). This disparity is of concern because emerging research suggests that studying cellular sex is important in developing stem cell therapies (see Case Study: Stem Cells).
2. **Analyzing Factors Intersecting with Sex to Avoid Overemphasizing Sex Differences.** Not all observed differences between female and male animals, cells, or tissues—or between women and men—are due to biological sex. Analyzing factors intersecting with sex and gender is critical to avoid overemphasizing sex differences. Important factors include diet, hormone levels, and species. Maternal interactions shortly after birth contribute to sex differences in behaviour: Mother rats interact differently with female and male pups, producing developmental differences (Moore, 1992).
3. **Developing Animal Models of Menopause.** High-quality, validated animal models of menopause are needed. Although primates undergo menopause-like processes, the challenges of using primates and the scarcity of older female animals limit research. Menopause can be induced surgically in experimental animals through ovariectomy, which models bilateral oophorectomy in women but may not be comparable to natural human menopause (Bellino et al., 2003). Strategies for modeling human menopause in rodents include treating mice or rats with drugs that induce premature ovarian failure and using transgenic mice (such as strain Foxo3a-/-) that show accelerated ovarian senescence (Wu et al., 2005).

4 **Studying Gender in Animal Research.** Placing female and male animals in different physical and social environments can have marked effects on behaviour and experimental outcome, and gender analysis is needed to ensure that housing systems and handling do not create systematic bias (Holdcroft, 2007). In particular, if researchers expect a particular sex difference, they may handle or house female and male animals differently and in such a manner as to produce that sex difference, or they may choose a specific behavioural test likely to produce that difference (Birke, 2011). Housing and handling can determine animal stress levels, which alter both behavioural and biochemical profiles (Beck et al., 2002).

B. Policy next steps:

1. **Requiring Researchers to Report the Sex of Subjects.** Granting agencies and journal editors can make sex reporting a requirement if research is to be funded or findings

published. Reporting the sex of model organisms prevents inappropriate generalizations, facilitates meta-analysis, and can show where animals of one sex have been overlooked. Major bioscience funders, including the U.K.'s Medical Research Council (MRC), now require that researchers report animal "species, strain, sex, developmental stage [...] and weight." Major journals, including *Nature* and the Public Library of Science publications, have instituted the same requirements (National Centre for the Replacement, Refinement, and Reduction of Animals in Research, 2008; Kilkenny et al., 2010).

2. **Requiring Two-Sex Studies and Sex Analysis.** Government agencies can require that, where appropriate, publicly funded studies include animals of both sexes and be designed with "adequate sample sizes" for each sex. Public and private funders alike can "treat inclusion of female animals as a matter of scientific merit that affects funding" (Beery et al., 2011).
3. **Standardizing the Use of "Sex" and "Gender" in Relation to Animal Research.** Currently, the terms "sex" and "gender" are used interchangeably in much animal research, complicating literature searches and meta-analysis. Sex and gender are not interchangeable. Standardizing usage, and using "sex" to refer to the biological trait of femaleness or maleness, would remedy this problem (Marts, 2004).

Stem Cells: Analyzing Sex

The Challenge

Taking sex into account can advance basic knowledge regarding stem cells—demonstrating potential sex differences in therapeutic capacity as well as sex differences in receptor-mediated pathways. Basic knowledge of stem cell biology is important to one of the most active areas of stem cell research: inducing pluripotency in cells derived from adult patients and using these cells to repair or reconstruct organs.

Gendered Innovation 1: Identifying Sex Differences in Stem Cell Characteristics

Research using sex as a variable has revealed sex differences in the properties of some adult stem cells. Findings include:

1. **Differences in Mesenchymal Stem Cell (MSC) Activation.** Mesenchymal stem cells, which can be derived from bone marrow and other tissues, can differentiate into bone, fat, muscle, connective tissue, and cartilage (Oreffo et al., 2005). Crisostomo and colleagues demonstrated that sex differences exist in the activation of mesenchymal stem cells (MSC). Researchers stressed murine MSCs in vitro with hypoxia, lipopolysaccharide (LPS), and hydrogen peroxide; they demonstrated that "activation" differed by cell sex: XX cells produced more vascular endothelial growth factor (VEGF, which promotes cell proliferation) and less tumor necrosis factor alpha (TNF-α, which promotes inflammation and apoptosis) than XY cells (Crisostomo et al., 2007).

2. **Differences in Muscle-Derived Stem Cell (MDSC) Regenerative Capacity.** MDSCs have the capacity for myocardial repair as well as skeletal muscle repair. They may also be useful for treating muscular dystrophy, for which existing treatments have limited effect (Jankowski et al., 2002).

   MDSC cell lines display variability in regenerative ability. Using mdx mice, which spontaneously develop muscular dystrophy, Deasy et al. demonstrated that cell sex, independent of other variables such as immune response and exogenous estrogenic effects, exerts a strong effect on regenerative capacity. The mechanism behind these differences is an active area of research.

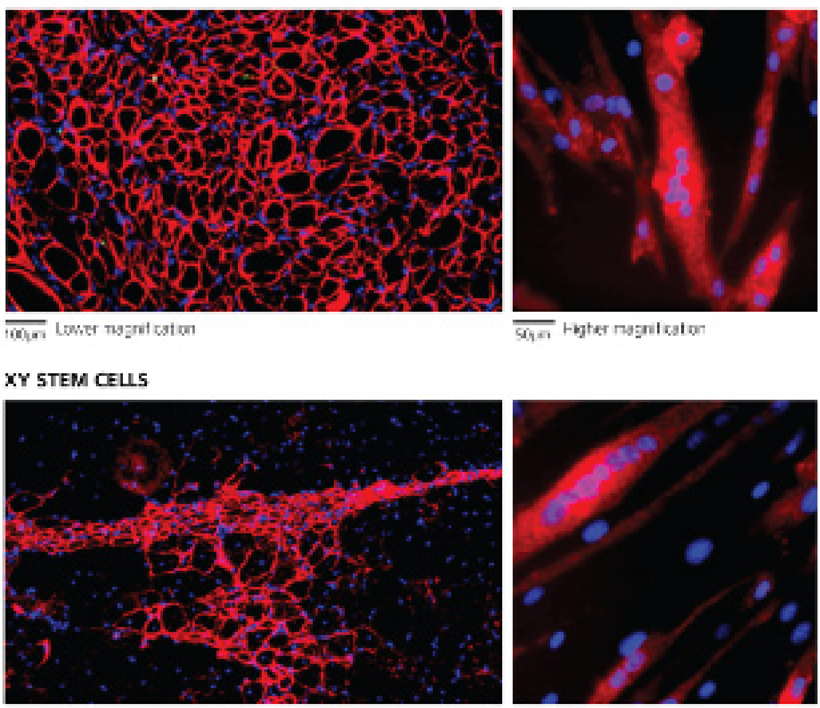
   Deasy et al. found significant sex differences in regeneration capacity in vivo, with XX cells yielding a higher regeneration index (RI) than XY cells. In vivo studies took advantage of the fact that mdx mouse muscle fibers lack the protein dystrophin; researchers determined RI by quantifying muscle fibers generated from stem cells (i.e., those with dystrophin). Even though all MDSCs could differentiate into dystrophin-expressing fibers in vitro, only XX MDSCs could regenerate robustly in vivo (Deasy et al., 2007).

Magnified Muscle Fiber Developed from XX and XY Stem Cells

After two weeks' development in *mdx* mice

XX STEM CELLS

XY STEM CELLS



These micrographs show muscle fibers produced from XX and XY MDSCs and demonstrate that XX MDSCs induce "more efficient skeletal muscle generation" than their XY counterparts based on the number of dystrophin-positive muscle fibers produced for a given number of donor cells. Muscles were harvested after two weeks of development in mdx mice. Dystrophin-containing muscle fibers are stained red, indicating that they arose from transplanted stem cells, as mdx mice lack a functional dystrophin gene and develop a syndrome similar to muscular dystrophy in humans. Nuclei are stained blue. Reproduced with permission from Deasy et al., 2007.

These sex differences may be therapeutically relevant—but because many variables besides sex influence cell behaviour, and because the traits of an "ideal" cell type differ depending on the therapy in question, such differences do not indicate that cells of a given sex are broadly therapeutically superior to cells of the other sex. In clinical research using stem cells, there is a "lack [of] direct comparisons of different cell types in clearly defined, clinically relevant models of disease" (Zenovich et al., 2007).

Gendered Innovation 2: Understanding Differences within and between XX and XY Stem Cells

Knowing that sex differences exist in stem cells, researchers sought to elucidate the causes of these differences—work that required analysis of additional factors (see Method).

Method: Analyzing Factors Intersecting with Sex and Gender

Researchers who analyzed sex have observed differences between XX and XY stem cells, but a deeper understanding of stem cell biology requires examination of covariates. Observed sex differences can arise in several ways:

1. Genetics: Female and male stem cells differ in karyotype and therefore differ genetically, but genetic variations also exist between cells of the same sex—not all XX cells or XY cells are alike. Studying the covariates of genotype and investigating both between-sex and within-sex differences is important in stem cell research.
2. Hormonal Environment: Stem cells are sensitive to hormonal environment—often including, but not limited to, the presence of sex hormones. Hormones can have both transient and permanent effects on stem cells, making hormonal environment a necessary covariate to sex (Asselin-Labat et al., 2010).
3. Epigenetics: The DNA sequence of a stem cell is unchanged throughout the cell's life and is rarely altered by environment. Gene expression, however, can change frequently and dramatically; indeed, such changes account for the ability of genetically identical stem cells to differentiate into functionally distinct somatic cells. These changes are heritable, and so even if cells are cultured in vitro in identical hormonal environments, observed differences cannot be assumed to stem from genetic sequence alone. The environments in which these cells' ancestors developed may have created epigenetic differences, and they are important covariates (Ohm et al., 2009).

Multivariate studies include sex as one variable among many. It is important to test for interactions between sex and other predictors of the outcome under study. Without such testing, one might attribute variability to sex when that difference is actually dependent on another factor. This misattribution can lead to overemphasis of sex differences. Covariate analysis has shown the following:

1. **Species influences stem cell behaviour, and findings in animal models are not necessarily applicable to humans.** For example, when pluripotency is induced in murine XX

fibroblasts, the resultant induced pluripotent stem cells (iPSCs) show a reversal of X inactivation, with two active X chromosomes. When human XX fibroblasts are treated to induce pluripotency, however, the resultant human iPSCs display one active and one inactive X chromosome (Tchieu et al., 2010).

2. **In mouse models of muscular dystrophy, both the sex of the donor cell and the sex of the recipient animal matter.** Multivariate analysis shows that XX MDSCs promote regeneration more than XY MDSCs (regardless of recipient sex) and that female recipient animals undergo more regeneration than male recipient animals (regardless of donor cell sex). In the mdx model of muscular dystrophy, matching donor sex to recipient sex would not be an optimal strategy for promoting muscular regeneration: XX stem cells are a better treatment option for both females and males (Deasy et al., 2007).

   Further experiments using immune deficient mice suggest that the effect of host sex (but not the effect of cell sex) is immunologically modulated: Researchers "observed no significant difference as a result of host sex" in immune deficient animals, "yet the significant difference as a result of cell sex remained" (Deasy et al., 2007).

3. **Even when sex is a statistically significant predictor of stem cell behaviour, not all cell lines are alike within a sex.** Mouse MDSCs show significant variation in regeneration potential within a single sex (Deasy et al., 2007).

   Studies of the 17 human embryonic stem cell lines commonly used in research (9 of which are 46,XX and 8 of which are 46,XY) have shown that different lines have different tendencies to develop into particular types (Osafune et al., 2008). These characteristics could not be predicted on the basis of karyotypic sex alone (Cowan et al., 2004).

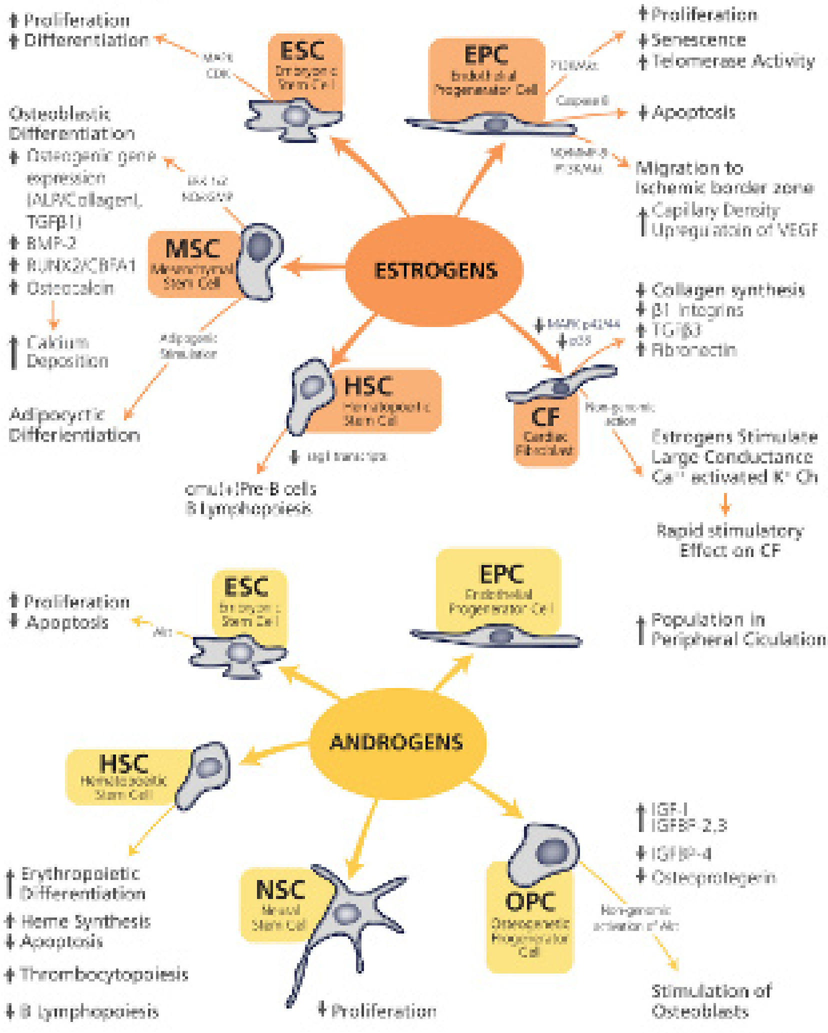
4. **Hormonal Environment Interacts with Stem Cell Sex.** The relationships between stem cells and hormones are complex—requiring consideration of the hormonal environment within which a cell or its ancestors developed as well as its current environment, whether in vitro or in vivo.

   A review by Ray et al. (2008) demonstrates that sex hormones influence the characteristics of many types of stem cells with effects that vary according to cell type:

Gendered Innovation 3: Improving Clinical Guidelines for Stem Cell Therapies

When a patient's own stem cells cannot be used therapeutically, success in stem cell transplantation depends on analyzing the interactions between: 1) the sex of donor cells used; 2) the sex of the host; 3) the type of stem cells transplanted; and 4) the illness being treated (see Method).

Effects of Estrogens and Androgens on Human Stem Cells and Progenitor Cells
Effects vary by cell type



Adapted from Ray et al., 2008

Method: Formulating Research Questions

Discoveries about the interactions between species, stem cell sex, recipient sex, and hormonal and immunological variables in animal and *in vitro* research have prompted researchers to formulate questions relating to stem cell therapies for human patients. Currently, the only stem cell therapy in standard medical practice is hematopoietic stem cell (HSC) transplantation, used primarily to treat malignant disorders but also used in patients with immune deficiency or aplastic anemia (Gratwohl et al., 2010).

A study of 1,386 patients undergoing allogeneic HSC transplantation at a single medical center (about 75% for leukemias and the remainder for other conditions) showed that sex matching between donors and recipients correlated with better overall survival, although HSCs from male donors were associated with better long-term survival (Pond et al., 2006).

In pediatric leukemia, HSC transplantation from a female donor to a male recipient produces outcomes that are "unfavorable comparing with all other sex combinations" and "dismal in the presence of an MM (Human Leukocyte Antigen Mismatch)." Donor pregnancy was also found to interact with donor sex and recipient sex; when stem cells are derived from pregnant women donors and given to male patients, the risk of graft-versus-host disease increases (Gustaffson et al., 2004).

Donor and recipient sex also interact with the covariate of disease type—for example, when HSC transplantation is used to treat multiple myeloma, cells from female donors may produce better outcomes. Women patients who receive female HSCs have lower mortality than women patients treated with male HSCs. For men patients with multiple myeloma, the sex of donor cells did not significantly influence overall mortality, but did influence modes of mortality: Men patients treated with male HSCs were more likely to die from myeloma relapse, whereas men patients treated with female HSCs were more likely to die from non-relapse-related causes, such as graft-versus-host disease (Gahrton et al., 2005).

Systems for matching patients to donors for allogeneic HSC transplants now take donor sex and patient sex into account, along with numerous other variables, in order to optimize outcomes (Lee et al., 2007).

Conclusions

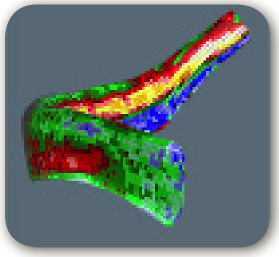
Researchers who reported and analyzed sex at the cellular level have identified sex differences in cell behaviour that may be of relevance in developing therapeutics. These findings led researchers to investigate the causes of sex differences and discover both hormonal and genetic factors that govern stem cell behaviour. In hematopoietic stem cell transplantation—the only stem cell therapy in widespread clinical use—clinicians have gathered data about interactions between donor sex, recipient sex, and other covariates in order to optimize donor-patient matching for allografts.

Next Steps

In basic research, scientists should be aware of the importance of sex as a variable and, in turn, identify the karyotype of cells used when reporting their research results. Results and null results should be reported (see Method: Analyzing Sex). Reporting cell karyotype is important whether or not sex-based differences exist because this information permits secondary research reviews and meta-analyses. Granting agencies and journal editors can encourage such reporting through grant and publication guidelines.

ENGINEERING AND TECHNOLOGICAL DEVELOPMENT

Human Thorax Model: Rethinking Standards and Reference Models



The Challenge

Road traffic collisions are a major cause of mortality and morbidity in the European Union and the US; in 2009, collisions resulted in an estimated 34,500 deaths in the EU-27 and 30,862 deaths in the US (Eurostat, 2011; NHTSA, 2012). Collision deaths are concentrated among young people, accounting for 12% of the overall deaths of people aged 19 and younger in the EU-27. Deaths are also concentrated among men. In both the EU and US, men are 2.6 times as likely as women to die in road collisions (DG Energy and Transport, 2009; Kposowa et al., 2009).

Multiple research projects have been undertaken with the goal of developing a finite-element model of the human body to enhance safety engineering. Consistently, models have been initially based on 50th percentile male anthropometry, with some models later expanded to include larger and smaller bodies (Yang et al., 2006). Following this pattern, the Human Model for Safety (HUMOS-1), funded under the EC Fourth Framework Programme (FP4) from 1997 to 2000, was based on the study of a single male cadaver, representing “a 50th percentile seated man” (Pajon et al., 2002).

HUMOS-2, funded under the EU FP5 from 2002 to 2006, expanded data collection to include humans from the 5th, 50th, and 95th percentiles—i.e., lighter people (mostly women) and heavier people (mostly men) (Njilie et al., 2010; Acar et al., 2009a; Dupont-Kerlan et al., 2006). Biofidelic models are, however, still developed first for the 50th percentile man, from the outset excluding people who are significantly smaller or larger. One such example is the Global Human Body Models Consortium (GHMBC) model (GHMBC, 2012).

Background

The EU FP7 Thorax Model (THOMO) project aims to develop a numerical, “finite element model of the human thorax and upper extremities” (THOMO, 2012). Data-gathering procedures by THOMO and associated research teams can be sorted into two basic categories:

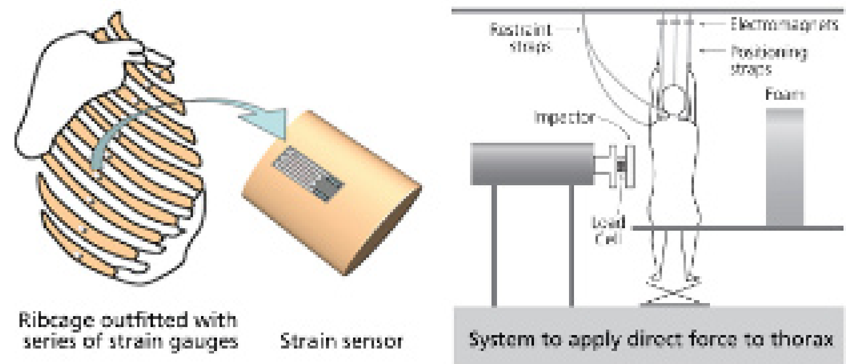
A. Measurement of the thoracic skeleton (imaging of ribs, sternum, vertebrae, and cartilage) with computed tomography (CT), laser scans, and microtomography (μCT) (Mayeur et al., 2010)—see image below.

Measuring Technologies for Obtaining Anthropometric Data

Adapted from Mayeur et al., 2010

B. Biomechanical stress tests on cadaver ribcages. Dynamic test endpoints include deformation under strain and actual fractures—see image below.

Technology for Measuring Deformation of Human Thorax



Adapted from Trosseille et al., 2008

Biomechanical tests are designed to simulate forces exerted on the thorax from both front- and side-impact automotive crashes. Tests cover a variety of scenarios, including drivers/passengers who are wearing 3-point seatbelts, wearing 4-point harnesses, or unbelted, in crashes with or without airbag deployment.

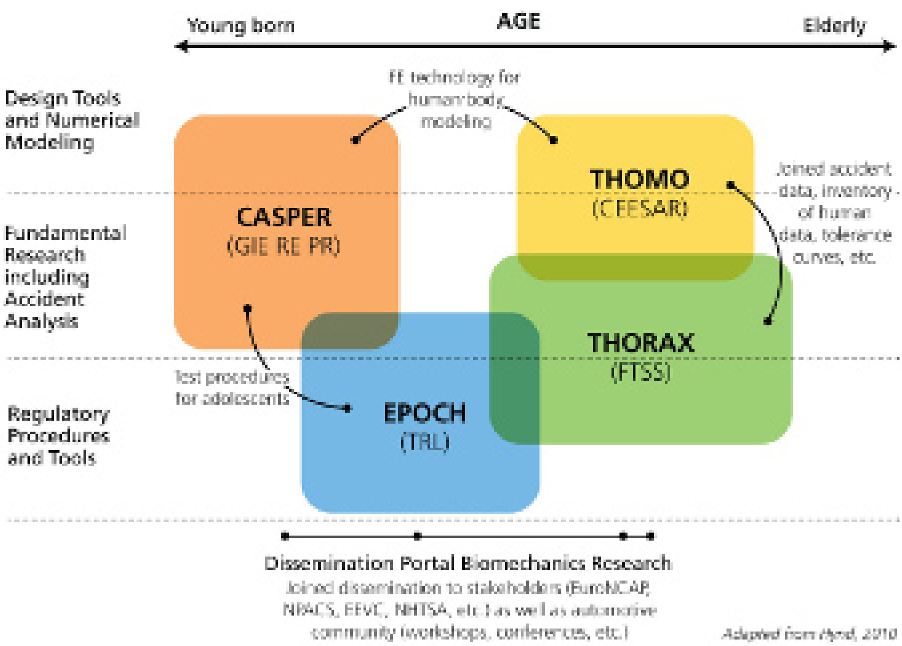
THOMO project measurements and biomechanical tests are performed on cadavers from France corresponding to the following percentiles of overall human body weight:

- 50th (11 male cadavers and 1 female cadaver)
- 5th (6 female cadavers)

THOMO uses scaling to model other size percentiles (THOMO, 2012).

THOMO is one of four biomechanical modeling projects under the EU's Coordination of Vehicle and Road Safety Initiatives (COVER) consortium. All COVER projects are funded under FP7 and each has a distinct focus (Lemmen et al., 2009)—see diagram below.

Relationship Between the FP7 Projects under the COVER Consortium



The THOMO project is one of several Centers of Expertise for the privately funded Global Human Body Models Consortium (GHMBC), which consists of nine automobile manufacturers from EU countries, the US, South Korea, and Japan, as well as the US National Highway Traffic Safety Administration (NHTSA) (GHBMC, 2012).

Automotive manufacturers continue to develop finite-element models for safety engineering purposes (Leonardi, 2009). One example is the Total Human Model for Safety (THUMS), a proprietary project of the Toyota Motor Corporation (Maeno et al., 2001). The initial version of THUMS was based on anthropometry of a 50th percentile US man (Chawala et al., 2005; Oshita et al., 2002). Currently, engineers are expanding the model to include 5th percentile American women, 95th percentile American men, and pregnant women (Iwamoto et al., 2007).

Gendered Innovation 1: Modeling Women's and Men's Thoraxes

The THOMO project models both women's and men's thoraxes by gathering data from bodies ranging from the 5th to 50th weight percentiles (THOMO, 2012).

Method: Rethinking Research Priorities and Outcomes

Studies of crash outcomes show that women drivers are approximately 47% more likely than men drivers to sustain severe injuries in automotive crashes when researchers control for factors such as height, weight, seatbelt usage, and crash intensity; that is to say, a seatbelt-wearing woman driver involved in a crash is more likely to be injured than a seatbelt-wearing man driver of identical height, weight, and age involved in an identical crash (Dipan et al., 2011; Evans, 1999). Several sex and gender factors may influence observed differences in crash outcomes:

1. **Injury threshold:** Women have a lower average injury threshold than men for some mechanisms of injury, such as whiplash, but young men have a lower velocity injury threshold than young women (Talmor et al., 2010; Stemper et al., 2004).
2. **Design:** Women may have excess risk because "effectiveness of occupant safety devices is biased toward the male occupants" (Dipan et al., 2011).
3. **Type of vehicle driven:** In the US, where data are available, women tend to drive cars with higher safety ratings than do men (Ryb et al., 2010).

Gendered Innovation 2: Consistent Biomechanical Testing of Female and Male Thoraxes

THOMO researchers have performed tests on small, mostly female thoraxes while maintaining consistency with instrumentation and data-reporting protocols previously applied to mostly male thoraxes. This method allows cross-sex comparison of strain profiles and the development of a more comprehensive reference model.

Method: Rethinking Standards and Reference Models

Physical strain tests are critical to developing biofidelic models.

Historically, a 50th percentile male cadaver thorax was used as a reference in frontal impact tests in EU-supported crash testing (Behr et al., 2003). This reference model did not account for lighter people's anatomy, and researchers who developed it recommended further work to "develop injury risk functions for female and elderly" drivers and passengers (Carroll, 2010). 50th percentile models also leave out larger people, and researchers assessing the "injury reduction potential" of automotive safety research assert that "the use of a larger than average size dummy could lead to the greatest benefit" (Carrol et al., 2010). THOMO researchers have worked to expand reference models of the thorax beyond the 50th percentile to include 5th percentile human body sizes. In light of this, THOMO researchers have prioritized creating a biofidelic, scalable model that better reflects the anatomy of both women and men.

Potential Value Added to Future Research through the Application of Gendered Innovations Methods

Potential Value Added 1: Studying the Effects of Age and Menopausal Status on Thoracic Bone Architecture

Inter-individual variation in the thorax extends beyond size and sex differences. Factors such as age and menopausal status influence bone mineral density (BMD) and microarchitecture, consequently altering biomechanical properties.

Method: Analyzing Factors Intersecting with Sex and Gender

Factors relevant to the THOMO project include:

1. **Age.** BMD increases slowly from birth to puberty, and rapidly for several years after puberty, before reaching a plateau extending into the 30s and then gradually declining with advancing age. There are sex differences in developmental BMD trends; for example, because puberty occurs earlier in women than men, women reach peak lumbar spine BMD earlier (at age 18-20) than men (at age 20-23) (Boot et al., 2010). Sex differences are also observed in BMD decline, which starts earlier in men but occurs more rapidly in women, particularly after menopause (Min et al., 2010; Li et al., 2003).

   Both biomechanical experiments on cadavers and epidemiological studies of injury elucidate the relationship between age, BMD, and bone strength. Biomechanically, volumetric BMD is a strong predictor of fracture threshold (Diederichs et al., 2009). Epidemiologically, "a consequence of decreased skeletal and physiological resilience [with increasing age] is that trauma and its sequelae are among the top ten causes of death in the 65-and-over population, with motor vehicle crash [...] being one of the most common sources of such trauma" (Gayzik et al., 2008).

   For these reasons, performing biomechanical tests on female and male cadavers of various age groups may be relevant to developing the thorax model.

2. **Menopausal Status.** In women, menopause results in both acceleration of BMD loss and changes in bone microarchitecture (Sowers et al., 2010; Müller, 2005). For these reasons, performing biomechanical tests with bones from both pre- and post-menopausal female cadavers may increase the THOMO's biofidelity for a broader population.

These factors may be challenging to analyze because of limited availability of cadavers and limited resources. If they cannot be fully incorporated into the THOMO model during development, they may be considered during validation.

Potential Value Added 2: Including Geographically Diverse Populations

The size percentiles used by THOMO researchers reflect body weight. Although sex differences in average body weight exist, sex is not the only predictor of weight—nor, necessarily, the most important. Body weight differs by country, and studying diverse cadavers may broaden the applicability of THOMO.

Method: Analyzing Factors Intersecting with Sex and Gender

Systematic comparisons of body weight between countries are challenging. Most databases report body mass index (BMI), not body weight itself, because BMI is a better indicator of the epidemiology of obesity and malnutrition (Finucane et al., 2011). Nevertheless, existing data do show substantial differences in body weight between countries, and country differences can be larger than sex differences. For example: The average US man weighs 16% more than the average US woman (Ogden et al., 2004); the average Korean man weighs 21% more than the average Korean woman (Nam-Kyu, 2009). Assuming equal sex ratios in the US and Korea, the average US person weighs 29% more than the average Korean person. In fact, the average US woman weighs more (74 kilograms) than the average South Korean man (69 kilograms) (Nam-Kyu, 2009; Ogden et al., 2004).

Potential Value Added 3: Modeling Breast Tissue

Researchers may enhance biofidelic models by examining research questions about the significance of breast tissue in automotive collision injury.

Method: Formulating Research Questions

Breast tissue is significant in two ways: first, direct injury to the breast; second, differences in seatbelt positioning that may have broad effects on crash safety.

A. Injury of the Breasts in Automotive Collisions. Seatbelt usage greatly increases occupant safety in a crash, but compressive and shearing stresses produced by three-point seatbelts can cause specific chest injuries, including damage to breast tissue, though these are rare (Paddle et al., 2009). Breast tissue injuries range in severity from mild crush injuries with bruising to severe breast trauma involving avulsion of the breast from the chest wall and internal hemorrhaging due to rupture of intracostal blood vessels (Paddle et al., 2009).

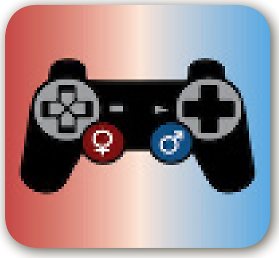
Breast injury is of particular concern in nursing women, as it can cause milk ducts to rupture (Sircar et al., 2010). Specific concerns also apply to women with breast implants (Gatta et al., 2006).

Injury to soft tissue in the breast area is not unique to women. Cases of Mondor's disease—caused by damage to veins in the chest wall—have been reported in both women and men subsequent to crashes in which the patient was wearing a seatbelt (Gatta et al., 2006).

B. Breasts and Seatbelt Positioning. Some women may wear seatbelts improperly because of discomfort caused by the placement of the shoulder harness over the breasts. Improper seatbelt usage greatly increases overall injury risk in a crash (Nordhoff, 2005).

During pregnancy, “anthropomorphic changes occur throughout the body and are not limited to the abdominal region,” and changes in breast size “are particularly important because they can influence the fit and positioning of the seatbelt” (Acar et al., 2009). Seatbelt designs that accommodate abdominal depth up to 95th percentile non-pregnant women fail to account for the 62% of third-trimester pregnant women who have greater abdominal depth (Acar et al., 2009a). Researchers are actively developing finite-element models to improve automotive safety for pregnant women (Acar et al., 2009b) (see Case Study: Pregnant Crash Test Dummies).

Video Games: Engineering Innovation Processes



The Challenge

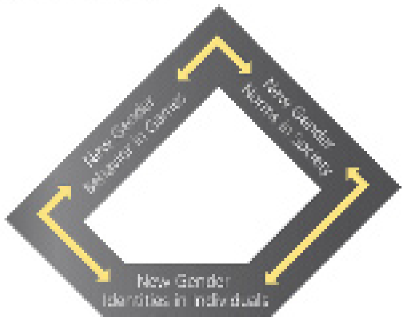
In 1962, MIT student Steve Russell created *Spacewar!*, the first widely-distributed software video game (Rockwell, 2002; Graetz, 1981). Until games were commercialized in 1971, game developers and players were primarily computer scientists, electrical engineers, and their students (Herman et al., 2002). Video games thus emerged from an environment where women were—and, to a large degree, remain—underrepresented (see Gendered Innovations website, Institutional Transformation, Disparities).

Gendered Innovation 1: Games as a Catalyst for Changing Gender Norms

Researchers are interested in how games—and the cultures that form around them—influence players’ real-world behaviours. Controlled experiments show, for example, that violent game play (in first-person shooter games, such as *Wolfenstein 3D,* or third-person fighter games, such as *Mortal Kombat*) increases the incidence of self-reported aggressive thoughts in the short term (Anderson et al., 2004; Anderson et al., 2007; Bushman et al., 2002; Gentile et al., 2004). Research has also shown that prosocial games in which the goal is “to benefit another game character” can make gamers more likely to take prosocial action (defined as voluntary actions intended to help others; Greitemeyer et al., 2010).

If games influence social behaviour, they may also catalyze social change (Stefansdóttir et al., 2008). Game researchers have found that games embed "beliefs within their representation systems and structures, whether the designers intend them or not" (Flanagan et al., 2007). Games can either reproduce gender stereotypes or challenge them—in ways that lead players to rethinking gender norms. Analyzing gender assumptions has led to understanding how games provide a virtual space where designers and players can explore gender identities and behaviours. Games that challenge conventional sex and gender stereotypes allow players to create multiple femininities and masculinities in a range of particular contexts and over time.

Games Provide a Cultural Space to Explore Gender



Method: Rethinking Language and Visual Representations

Games provide a virtual space where designers and players can experiment with gender norms, relations, and identities. Video games allow players to experiment in ways that might be difficult or impossible in the real world (Turkle, 1997). A cross-sectional study of gamers found that—when given choices—54% of men and 68% of women engaged in "gender-swapping"; these players felt more freedom to experiment in game play than in real life (Hussain et al., 2008). Players might also engage with gender-ambiguous characters (Conrad et al., 2010).

In addition to sex and gender, gamers can and do experiment with other factors such as race, age, height, and so on (Harris et al., 2009). Challenging traditional stereotypes, not just reversing them (by making "women warriors," such as Lara Croft) has the potential to help remake real-world gender identities and behaviours.

Challenging gender stereotypes may enhance diversity in video and online games, and potentially the gaming industry. This is important because games are increasingly spaces where young people engage in a significant portion of their socializing.

Designing Games for Girls: The Problem of Stereotypes

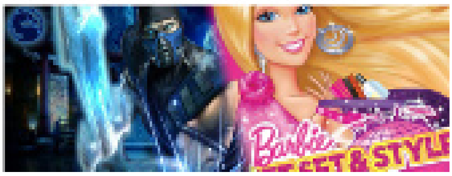
In the 1990s, researchers estimated that the majority of games were purchased for boys (Cassell et al., 1998). Recognizing this, a number of gaming companies developed strategies to increase play among girls, including:

1. **Encouraging girls to play boys' games.** The effort to make girls competitive players in boys' games is an assimilationist approach, aligned with liberal feminism. Liberal feminism generally seeks to provide girls with the skills to make it in a boys' world. In this instance, the games remained the same; girls learned how to play them better. The main

problem with this approach is that neither games nor societies change; efforts are focused on teaching girls new skills (Cassell et al., 1998).

2 **Designing games for girls.** The 1990s saw the bifurcation of gaming along stereotypical gender lines. "Blue" games catered to boy's perceived interests, which included combat and sports. Often violent, these games featured few women characters, and those were likely to be highly sexualized or victimized. "Pink" games, by contrast, were "girly," typically presenting fashion and princess themes. These games included *Barbie Fashion Designer* and *Cosmopolitan Virtual Makeover* (Dickey, 2006).

Stereotypical "Blue" and "Pink" Games
Mortal Kombat vs. Barbie Jet, Set, and Style



The 1990s also saw the introduction of "purple" games, which placed "less emphasis on the ultra-feminine aspects of young girlhood than pink games" (Kafai et al., 2008). Although the term "purple" might suggest unisex games, purple games such as the Nancy Drew series (by Her Interactive) and the Friendship series (by Purple Moon) still targeted girls (see Gorriz et al., 2000 for a list of these games).

Developing games specifically for girls is an approach associated with "difference feminism." Critics have argued that pink games promote gender stereotypes and essentialism, and they tend to overemphasize gender differences (Jansz et al., 2010)—see Term.

Term: Stereotypes

Video game players are often stereotyped as "male and young, pale from too much time spent indoors, and socially inept" (Williams et al., 2008). These stereotypes mark video games as "the province of boys and men" (Jenson et al., 2011; Toto-Troconis et al., 2010). Such beliefs have been internalized; even kindergarten girls and boys report that video games are more appropriate for boys than for girls (Lucas et al., 2004).

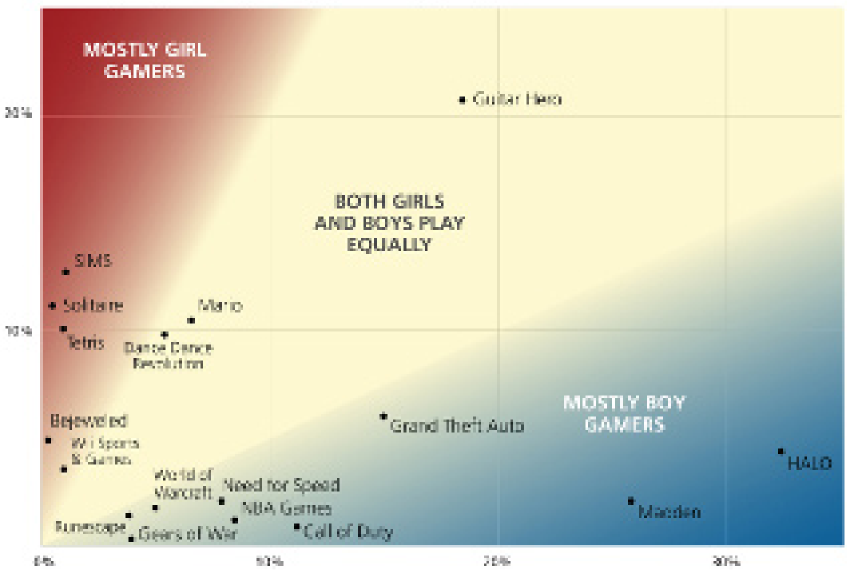
Parents' attitudes also reinforce stereotypes. For example, the designers of *KidCom*, a communication game made specifically for girls age 7-12 in the Netherlands, found that girls did not like pink, but they designed the device in a pinkish color anyway because this best satisfied the (paying) parents' expectations (Sørensen et al., 2011).

Gendered Innovation 2: Designing Flexible, "Gender-Mixed" Games

"Pink" and "blue" games reinforce traditional gender stereotypes. Stereotypes tend to exaggerate gender differences between girls and boys, women and men. This dichotomous thinking can result in unsuccessful game design. With the exception of *Barbie Fashion Designer*, video games designed specifically for girls have not been commercially successful (Gorriz et. al., 2000; Sørensen et al., 2011).

One way to overcome stereotypes is to collect empirical data about who plays video games and what games they play. Although data are rare, evidence from several large studies suggests that designers may benefit from creating games that are "gender-mixed," appealing to both girls and boys (Rommes et al., 2010; Faulkner et al., 2007). A 2007–2008 Pew Research Center study of 1102 US 12- to 17-year-olds and their parents found that the most widely played game, *Guitar Hero*, was equally popular among these girls and boys (Lenhart, 2008b)—see chart. None of the games designed for girls in the 1990s ranked among the top ten for either sex.

Game Preference by Gender
Percentages of girls and boys who play the most popular games



The Pew study confirms that girls and boys play different games: Girls are more likely to play puzzle and simulation games, whereas boys are more likely to play combat and sports games. Yet there is also great overlap in the games they play: Girls and boys are equally likely to play games categorized, for example, as "racing," "rhythm and music," "simulation," and "virtual worlds" (Lenhart et al., 2008b). This is consistent with findings that the games girls and boys play do not fall into simplistic categories of traditional feminine or masculine tastes (Faulkner, 2004). The classification of games into genres is complex and not an issue addressed in this case study.

Method: Engineering Innovation Processes

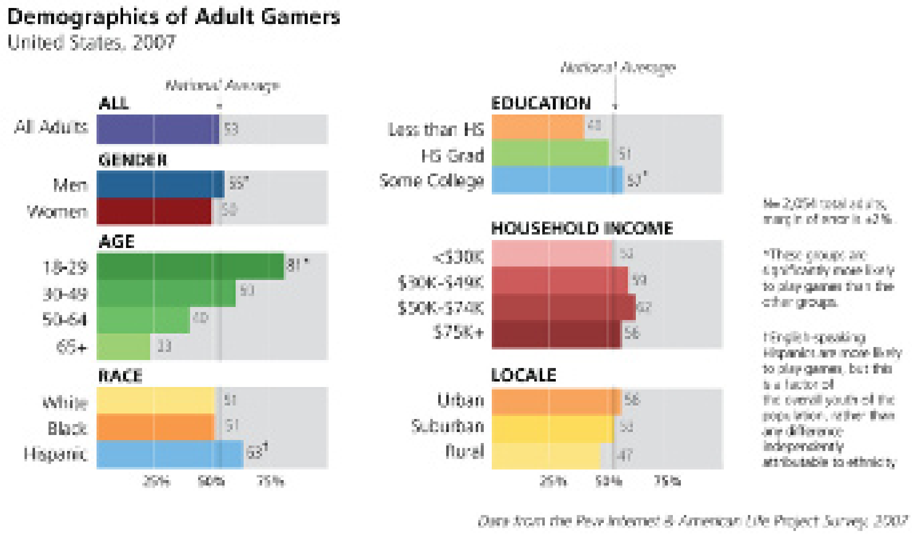
Considering the following points may lead to games designed with dynamic gender norms (Danilda et al., 2011; Sørensen et al., 2011; Rommes, 2006).

1. **In designing for "everybody,"** designers often unconsciously design for boys (Oudshoorn et al., 2004). The result may be games that boys prefer and an increased number of hours that boys play. This approach, however, misses boys who are not typical gamers.

2. **"I-Methodology"**—where designers assume that users will like the same things they do—may also result in games for boys: In the gaming industry, 88% of designers are men (Oudshoorn et al., 2004).
3. **Designing specifically for girls** can have multiple effects:
    a. Companies that focus on "what girls want" may find new markets. This strategy, however, can reinforce traditional stereotypes and may not achieve long-term success.
    b. Designers' beliefs about what girls like and what the market wants (what parents will buy) may lead to stereotypically feminine games. Girls may play different games from the majority of boys, but they don't necessarily play "pink" games, as we saw in the Pew study. This approach misses girls who do not fit the stereotype.
4. **User input**—from girls and boys—can be important (see Method: Participatory Research and Design).
    a. Surveying users may produce inaccurate data due to reporting bias: People surveyed tend to report behaviours that conform to stereotypes, even if their actual behaviours do not. As a result, self-reports may generate inaccurate data that appear to support stereotypes. For example, when parents and their children are surveyed about time spent playing video games, parents underreport their children's gaming hours relative to children's self-reports. The gap between child-reported and parent-reported playing time is much larger between daughters and their parents than between sons and their parents (Lenhart et al., 2008b).
    b. Objective measures of players' play behaviours may lead to better design.
5. **Which girls/women? Which boys/men?** Not all women (or men) are the same, and analyzing group heterogeneity may better capture the diversity of interests and tastes in broad populations. It is important to keep in mind that factors intersecting with sex and gender, such as age, educational level, or geographic location (urban vs. rural), can be more important to consider in game design than gender differences (Lenhart et al. 2008a)—see chart below.
6. **Including women** on the design team may broaden perspectives.
    a. Including women—their experiences, knowledge, and networks—enhances creativity and innovation (Danilda et al., 2011).
    b. Simply including women, however, may not be enough. One woman, for example, does not represent all women. To maximize innovation, everyone on the design team—women and men—will want to learn methods of sex and gender analysis.

Video Games and Women's Participation in Information Technology (IT) Industries

Gaming is often considered a gateway to careers in computer science and IT, but this may not be the case (Gros, 2007). In the past decades the number of women players has increased dramatically. Girls and women today are playing games more than ever before. Women are especially active in online games and social games played on networks such as Facebook (Taylor, 2003). The Entertainment Software Association found that in 2011 in the U.S, women were 42% of video game players overall and 48% of the most frequent purchasers of games (ESA, 2011).



The upsurge in girl gaming, however, has not led to women's increased representation in computer science. The proportion of women in computer science has decreased in most Western countries, falling from its peak in 1986 of 36% of undergraduate degrees to 21% in 2006 in the US (AAUW, 2010). In the European Union, women received 25% of ISCED level 5-6 degrees (tertiary degrees) in computing in 1998, but only 18% of such degrees in 2009. During this 11-year period, the absolute number of women computer science graduates increased from 14,505 to 25,764, or about 78%; the absolute number of men graduates, however, increased from 42,148 to 119,310, or about 181%, over the same period (Eurostat, 2011). Further, women are only 12% of the US video game workforce; as in most industries, they are particularly underrepresented in executive and technical positions (Haines, 2004; Fullerton et al., 2008).

Promoting game play among women is not enough. Engineering innovation through analyzing sex and gender is important to influencing social change. Methods of sex and gender analysis can help us rethink stereotypes and open design to dynamic representations of gender.

Conclusions

Design can promote gender equality. Games, in particular, can be a catalyst for change in gender norms, relations, and identities, and, eventually, in the gaming industry itself. Although gender norms determine in part the kinds of games that are produced, gender itself is dynamic and often produced during game play through player interaction. Games can have a powerful influence on players' gender attitudes and behaviours.

Next Steps

1. **Empirical data are required to understand gender differences and similarities** in gaming behaviours, skills, and preferences. Studies should include information about players' educational background, play experience, income level, regional location, and age.
2. **Designers may develop strategies to enhance gender flexibility** in games, allowing games to become experimental spaces for changing gender norms.

ENVIRONMENT

Climate Change: Analyzing Gender, and Factors Intersecting with Gender

The Challenge

Strategies for managing global warming fall into two broad categories: mitigation and adaptation. This case study focuses on mitigation in industrialized countries because these countries are responsible for the "largest share of historical and current global emissions of greenhouse gases" (United Nations, 2002). Mitigation involves strategies to slow anthropogenic climate change, typically by curbing emissions of greenhouse gases through changes in energy supply, transportation, agriculture, and urban infrastructure, as well as lifestyle (Barker et al., 2007). The European Institute for Gender Equality (EIGE) states that "there is a lack of awareness of [...] the gender aspects of mechanisms to mitigate climate change" as well as "a lack of research to inform debates on these issues" (EIGE, 2012).

Analyzing gender in climate change can support:

Equality: Environmental legislation, policies, and programs may have different effects on women and men—as well as people of different income levels, ages, and geographic locations (Denton, 2002). Gender analysis can contribute to policies that remedy—or at least do not exacerbate—existing social inequalities (EIGE, 2012; see Method: Rethinking Research Priorities and Outcomes).

Effectiveness: Policies and programs aimed at reducing energy consumption are likely to be more effective if gender analysis ensures that they reach both women and men (Alber, 2011).

Efficiency: All stakeholders (scientists, policy makers, consumers) should be involved in decision-making to help minimize the economic harm and maximize the ecological benefits of mitigation policies (Mearns et al., 2010; O'Neill et al., 2010).

Gendered Innovation 1: Understanding the Importance of Analyzing Gender in Relation to Intersecting Factors

This case study focuses on methodological approaches to gender analysis in climate change. From the start, gender analysis must avoid essentialism and over-emphasizing differences between women and men. Looking at women as an undifferentiated group and opposing this to men as an undifferentiated group (simply disaggregating data by sex) misses important factors influencing behaviours in relation to the environment. These factors include income, age, and geographic location.

Method: Analyzing Factors Intersecting with Gender Methodological Issues

Stereotype	Factors to Consider
Men have larger "climate footprints" than women.	Consider the following methodological factors when analyzing automobile-related emissions. 1. Attributing emissions? This may not be straightforward if multiple people (such as families or co-workers) ride together. For example, in private vehicles, women are more likely to be passengers, and men are more likely to be drivers (Ironmonger et al., 2007; Sarmiento, 1996). In this context, attributing all driving-related emissions to drivers might inflate men's apparent emissions. Similarly, women drive more often in support of other family members (children and the elderly) than do men (Mauch et al., 1997). In this context, attributing all driving-related emissions to drivers might inflate women's apparent emissions. 2. Gender behaviours vs. income? Men do not necessarily have a higher marginal propensity to emit (MPE) than women—that is, men do not necessarily emit more greenhouse gases (GHGs) per unit of earned income. For example, in New Zealand, where data are available, women drive on average 8,000 km/year and men 12,000 km/year (New Zealand Ministry of Transport, 2011). But median incomes are NZD 19,100 for women and 31,500 for men (Statistics New Zealand, 2012).

Stereotype	Factors to Consider
	Using a linear model, women drive 0.42 km per NZD of income, whereas men drive 0.38 km per NZD. Therefore, if one considers a woman and man earning the same amount of money (for example, NZD 25,000), a woman would be expected to drive farther than a man: 10,500 km vs. 9,500 km. This disparity is not universal: For example, in Sweden, estimates suggest that men drive farther than women both in an absolute sense and relative to their incomes (Johansson-Stenman, 2001). 3. Distance vs. fuel efficiency? Women and men may, on average, drive cars of differing fuel efficiency, fuel types, and so on. Some studies report that women consider fuel efficiency more than do men when evaluating vehicles (Achtnicht, 2012). Other studies find "no statistically significant effects" related to age, gender, or education (Popp et al., 2009). 4. Distance vs. driving conditions? Women and men might, on average, drive under differing conditions (city vs. highway, low vs. high traffic congestion, etc.). Such conditions influence fuel efficiency and complicate the process of converting distance driven into fuel consumed (Barth et al., 2008).
Women care more about the environment than men, and therefore produce lower emissions.	Consider the following methodological factors: 1. Differences in attitudes are important, but often small. For example, in a EU-wide study, 69% of women and 67% of men stated that climate change was "a very serious problem." Women (50%) and men (51%) are similarly likely to consider climate change to be among "the most serious problems currently facing the world as a whole" (Eurobarometer, 2009). 2. Income may intersect with gender as a predictor of climate concern (Franzen et al., 2010). 3. Education level and political affiliation may intersect with gender as a predictor of climate attitudes. In the US, where data are available, education and political affiliation interact: among self-identified Democrats, climate concern rises with increasing education; among self-identified Republicans, it declines with education (Hamilton, 2011).

Stereotype	Factors to Consider
Men have more knowledge than women about technical topics, including climate change.	Consider the following methodological issues: 1. Survey design: Survey instruments may affect judgments about women's and men's climate change knowledge. Surveys indicate that women are more likely to report "false positives" (incorrectly believe that a given factor does cause climate change), whereas men are more likely to report "false negatives" (incorrectly believe that a factor does not cause climate change) (O'Connor et al., 1998). 2. Self-reported vs. actual knowledge: In self-report studies, men may assert a greater level of climate knowledge than women (Eurobarometer, 2009). In tests of actual knowledge, results differ, with some studies showing no significant difference (McCright, 2010; Sundblad et al., 2007).

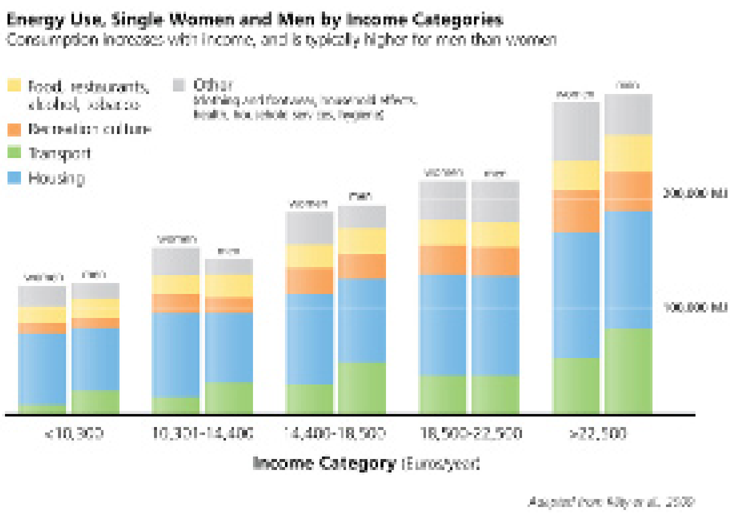
Sample Study

The chart below shows differences in energy use between single women and single men in multiple income categories (see source for definitions of income categories; Räty et al., 2009). Single persons were selected to avoid methodological challenges in attributing energy use to a specific individual within a multi-individual household. These data are:

1. Sex-disaggregated, allowing comparisons between women and men.

2. Income-disaggregated, allowing comparisons between people of different socioeconomic statuses.

3. Disaggregated by specific forms of energy consumption.



Data supporting this type of analysis are rare (EIGE, 2012). In lieu of comprehensive data, figures from Germany are presented. Methodological challenges in interpreting available data include:

1. Data do not directly reflect climate impact, as different forms of energy use have different climate impacts per megajoule (MJ) delivered (Granovskii et al., 2007).
2. Data are not necessarily representative of all Germans, as energy use patterns differ between single- and multi-person households (Brounen et al., 2012).
3. Data are likely to be non-representative of Europe as a whole, given that energy use—particularly for transport—differs between European countries (European Environment Agency, 2011).
4. Data do not reflect indirect climate impacts, which are significant for many energy sources. For example, transportation data consider only the direct release of GHGs from combustion engines—not the indirect release of GHGs associated with oil drilling, petroleum refining, fuel transportation, pipeline construction, and other production activities (Charpentier et al., 2009).
5. Data do not necessarily reflect energy usage or climate impact incurred outside Germany itself (Davis et al., 2010; Mahesh et al., 2010).
6. Data do not reflect climate impact incurred through mechanisms other than GHG emission, including: a) deforestation, which reduces absorbance rates of CO_2 in the biosphere (Watson et al., 2000); and b) changes in terrestrial or atmospheric albedo (Piekle et al., 2002).

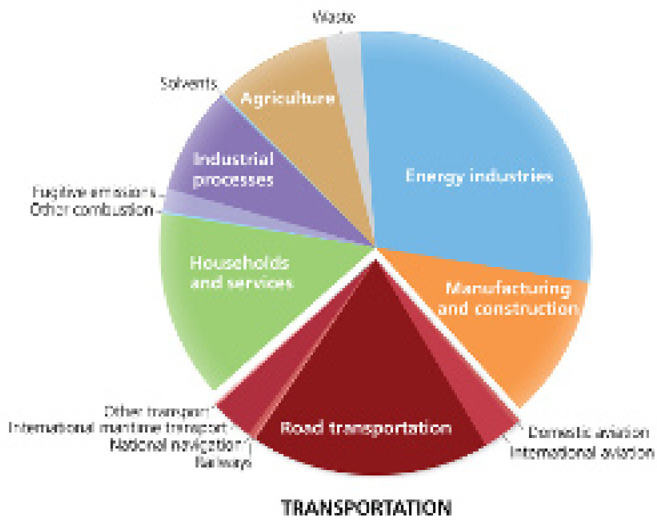
In Germany, single men consume on average 147,000 MJ/year, 37% more than single women's 108,000 MJ/year (not shown in graph above) (Räty et al., 2009). The majority of this difference disappears when data are corrected for income. For example, in the lowest income category, single men consume only 1% more energy than single women (119,601 MJ vs. 118,368 MJ). In the highest income category, single men consume 2% more energy than single women (292,221 MJ vs. 285,234 MJ). Highest-income women consume 141% more energy than lowest-income women; for men, the figure is 144%. Income is therefore an important factor to analyze when looking at women's and men's energy consumption.

We highlight the Räty et al. study because it is one of the few to consider gender behaviours in relation to other social factors. Looking at single women and men, however, does not take into consideration asymmetries in family relations: Women more often than men care for dependents (children and the elderly). An ideal study would compare women and men, controlling for all other relevant factors, including age, socioeconomic status, education, partnering status, household configuration (number of children and other dependents), geographic location (including density of settlement), and types of available transport. Occupation, age, geographic location, and household composition have all been shown to correlate with transport-related emissions in the United Kingdom (Brand et al., 2008). Future studies of gender in relation to climate change might consider these as other important intersecting factors.

Transportation

Within any given income group (see chart discussed above), energy consumption differences between women and men are most pronounced in transportation. In the lowest income category, men expend 160% more energy on transport than women (21,372 MJ vs. 8,220 MJ). In the highest income category, men expend 48% more energy (75,624 MJ vs. 50,964 MJ). These differences shrink as income increases, but they do not disappear. They are significant because transportation is a major source of GHG emissions—see below.

GHG Emissions by Sector in European Union
Transportation accounted for 25% of all emissions

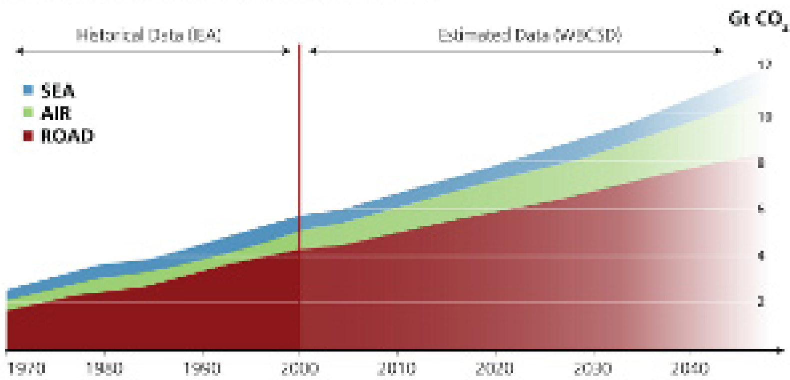


Data from European Union (27 Countries), 2009
Adapted from European Environment Agency, 2012

Policy Implications

Integrated public and private transportation systems will be an important part of the solutions. The International Energy Agency (IEA), United States Energy Information Administration, and World Business Council on Sustainable Development (WBCSD) all project worldwide transport energy consumption to increase 2% per year in the coming decades. As "almost all of this new [transport] consumption is expected to be in petroleum fuels [...] CO_2 emissions will essentially grow in lockstep with energy consumption" (Ribeiro et al., 2007)—see below.

Trends in Global Transport-Related CO_2 Emissions
Emissions estimated to grow in lockstep with production



Adapted from Ribeiro et al., 2007

Individual Consumer Choice

Individuals can do their part to reduce emissions. They can choose to walk, bicycle, or take public transportation when possible. They can choose smaller, more energy-efficient cars. They can carpool, or travel shorter distances for leisure. But user choice goes only so far. Urban planning and design are central to minimizing the need for transportation, to maximizing efficient public transportation, and to mitigating gender inequality (for designing cities to enhance gender equality, see Case Study: Housing and Neighborhood Design). Examples of projects include:

Cycling Promotion Projects: State and local governments are working to promote cycling as a form of transportation in order to reduce GHG emissions and promote health (Andersen et al., 2012; Bauman et al., 2008). For example, the Danish government is studying cycling through its "Bikeability: Cities for Zero Emission Travel and Public Health" project. The project supports research into how demographics, bicycle infrastructure, and overall city design influence cycling (Bikeability, 2012). Analyzing gender may be important to planning new cycling infrastructure—considering women's and men's travel patterns and behaviours may enhance cycle route planning.

Other factors, however, may intersect with gender. These include:

- **Geographic locations:** Available data suggest that women's and men's cycling behaviours differ substantially by location. In Denmark, for example, women are more than twice as likely as men to report commuting to work or school by cycling—36% versus 17% (Madsen, 2010). In the UK, women are only slightly more likely than men to report commuter cycling (Foster et al., 2011). In the US and Australia, men are about three times as likely as women to report commuting by cycling (Garrard et al., 2012; Garrard et al., 2008).
- **Age:** In Washington State, cycling was observed to be most common among adults age 25–45, declining at both lower and higher ages (Moudon et al., 2005).
- **Body Mass Index:** In a study of 13 countries, cycling was observed to be correlated to healthy weights (Bassett et al., 2008).
- **Income:** In Flanders, Belgium, low median income was associated with higher rates of commute cycling (Vandenbulcke et al., 2011).

Large-scale comprehensive studies provide limited information on the interaction between gender and other factors—more research is needed to increase understanding (Pucher et al., 2011).

Gender Budgeting in the Canton of Basel-Stadt, Switzerland: The Statistical Office of the Canton of Basel-Stadt collects sex-disaggregated data to inform transportation policy. Other variables are also considered—for example, the office has examined how both women's and men's transit expenditures change with age. The office also estimates how public funds spent on transport infrastructure benefit women and men (Office for Gender Equality of the Canton of Basel-Stadt, 2008).

Conclusions

Researchers are beginning to study climate change mitigation from a gender perspective. Efforts to analyze factors that intersect with gender—including income, age, travel patterns, geographic location, and environmental attitudes—contribute to a better understanding of climate impacts and responses to mitigation measures. This understanding may improve the effectiveness of mitigation strategies by ensuring buy-in from all energy users. It may also support efficiency and equality by achieving mitigation at the lowest possible social and economic cost, and by ensuring that costs are shared in equitable ways.

FOOD AND NUTRITION

Nutrigenomics: Analyzing Factors Intersecting with Sex and Gender

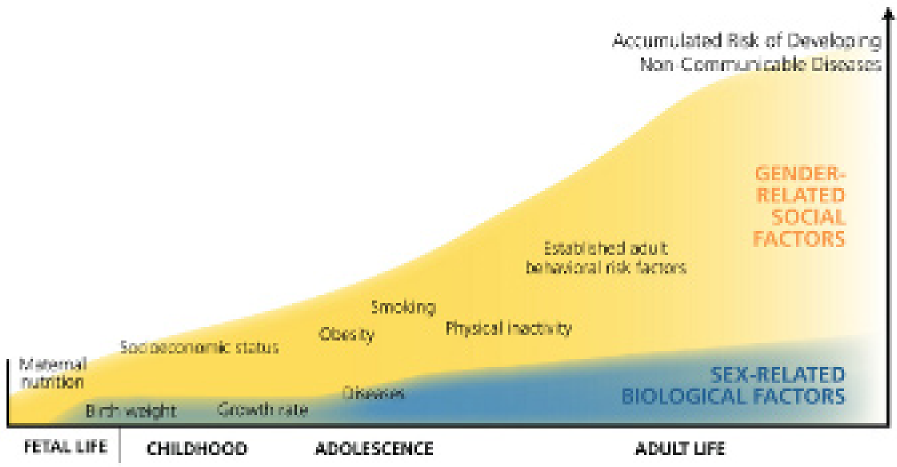
The Challenge

According to the World Health Organization (WHO), "in 2005, 35 million people died from non-communicable diseases (NCDs), which represents 60% of the total number of global deaths in that year. Moreover, between 2005 and 2015, yearly deaths due to NCDs are projected to increase by 17%" (WHO, 2009). Scientists estimate that elimination of modifiable risk factors, such as unhealthy diet, physical inactivity, and tobacco use, would prevent "80% of premature heart disease, 80% of premature stroke, 80% of type 2 diabetes, and 40% of cancer" (WHO, 2009). The prevalence of these risk factors, however, "varie[s] between country income groups, with the pattern of variation differing between risk factors and with gender" (WHO, 2011). The bases for this variability are multiple and still poorly defined. Gender and sex analysis provide a solid, mechanistic understanding of significant patterns of variation and will be essential to reducing NCDs in the decades to come.

Understanding Sex- and Gender-Related Variations in NCDs Risk Factors

NCDs are primarily caused by "preventable risk factors" and are "causally linked with four particular behaviours: tobacco use, physical inactivity, unhealthy diet, and the harmful use of alcohol" (WHO, 2011). Integrating sex and gender analysis into a life course approach can reveal how sex- and gender-related factors interact to influence the development of NCDs (Brands et al., 2002). For example, sex-specific biological factors determine responses to particular diets that make women and men more vulnerable to certain types of fat dispersions, and gender-related behaviours result in different levels of accumulated risk for "four key metabolic/physiological changes: raised blood pressure, overweight/obesity, hyperglycemia, and hyperlipidemia" (WHO, 2011). Analyzing various life stages, researchers can determine how sex-specific biological factors and multiple social factors combine to affect the health of women and men (see chart below).

Cumulative Life Course Risk Factors for Non-Communicable Disease (NCD)
Highlighting the influence of sex and gender-related factors



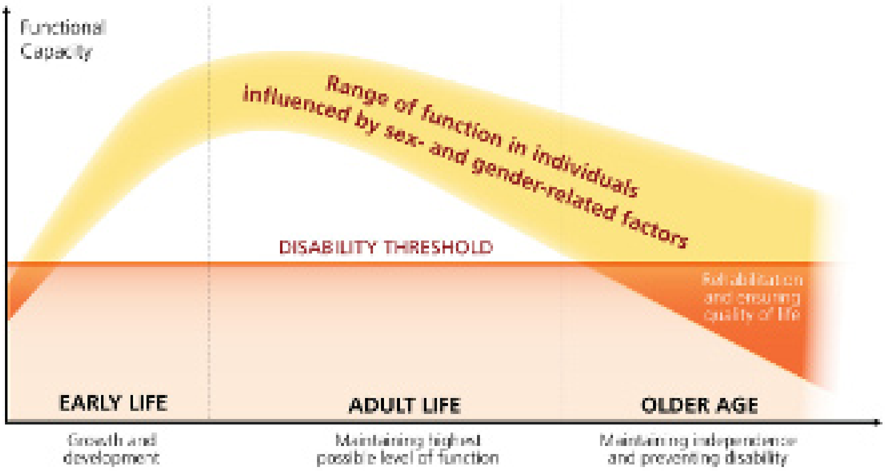
Adapted from Darnton-Hill et al., 2004

Method: Analyzing how Sex and Gender Interact

From a life course perspective, the relative influences of sex- and gender-related factors will determine an individual's functional capacity when aging. It is important to consider that both gender-related social factors and sex-related biological factors interact from early life onward. In the various stages of life, the resulting individual functional capacity is the product of both influences, and therefore it is hard to identify the respective influences of each factor independently.

Promoting healthy behaviours throughout the life course, particularly in adulthood, has been found to prevent the onset of NCDs (see chart below). Several clinical trials and population studies have established that "80% of cases of coronary heart disease (CHD) and up to 90% of type 2 diabetes could potentially be avoided through changing lifestyle factors, and about one third of cancers could be avoided by eating healthily, maintaining normal weight, exercising throughout the life span" (Darnton-Hill et al., 2004). In order to change or modify behaviours, however, the WHO states that it is necessary to examine how "prevailing social and economic conditions influence people's exposure and vulnerability to NCDs" (WHO, 2011). This includes accounting for factors that determine social and economic status, such as "education, occupation, income, gender, and ethnicity" (WHO, 2011).

A Life Course Perspective on Health and Aging
Highlighting the influence of sex- and gender-related factors

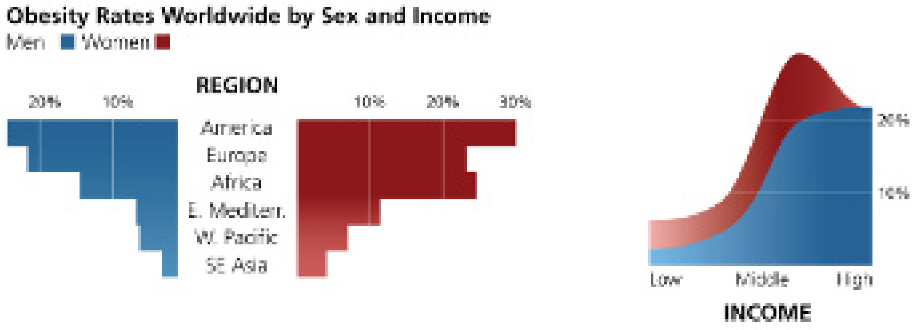


Adapted from Brands and Yach, 2002

Method: Analyzing Factors Intersecting with Sex and Gender

Obesity contributes significantly to the prevalence of NCDs. It has been directly linked to "adverse metabolic effects on blood pressure, cholesterol, triglycerides, and insulin resistance" and increases a person's risk of developing "coronary heart disease, ischemic stroke, and type 2 diabetes mellitus" and "cancer of the breast, colon/rectum, endometrium, kidney, esophagus (adenocarcinoma), and pancreas" (WHO, 2011). Globally, rates of obesity doubled between 1980 and 2008 and are increasing fastest among lower-middle-income countries as a result of modernization on lifestyle and food consumption practices (WHO/FAO, 2003; Popkin et al., 2004).

With the exception of high-income countries where obesity rates are roughly the same for women and men, women are significantly more likely to be obese than men in all regions and income groups (see charts below). There is, however, considerable variation in rates of obesity between women and men across these country groups. For instance, "in low- and lower-middle-income countries, obesity among women was approximately double that among men" (WHO, 2011). Obesity is generally attributed to physical inactivity and poor diet. To understand gender differences in rates of obesity, it is necessary to identify the various social factors that differentially limit women's and men's access to healthy food and physical exercise.



Data from World Health Organization, 2011

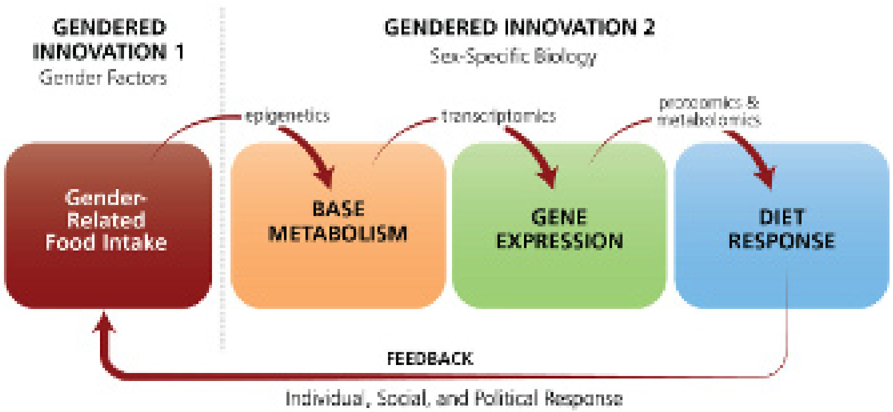
Gendered Innovation 2: Determining Sex-Specific Metabolism, Dietary, and Nutrient Responses

Knowledge of sex differences is essential to complement data from epidemiology in order to understand the biological factors that might be contributing to differences in risk factors, such as obesity. Nutrigenomics "examines the response of individuals to food compounds using post-genomics and related technology (genomics, transcriptomics, proteomics, metabolomics, etc.)." It can be thought of as "the study of how nutrients in food interact with our genes at the molecular and cellular levels, and the impact these reactions have on our health" (Bouwman et al., 2009). Gender-related food intake is a critical part of an individual's environment and life history. Environment, milieu, and diet are translated into biological variability through the study of epigenetics, analyzing how environmental exposure influences, among other things, metabolism (Niewöhner, 2011). The expectation is that information about an individual's genetic make-up can be combined with knowledge about the biological impacts of environmental context to better assess "personal physical vulnerability to diet-related diseases" (Bouwman et al., 2009).

Method: Analyzing Sex

Dietary recommendations aimed at preventing NCDs are currently a "one size fits all" recommendation. Early studies focused primarily on men. Only in the 1980s did studies begin to include women (i.e., the Nurses' Health Study, the Minnesota Coronary Survey, and the Finnish Mental Hospital Study) and contradict earlier results. For example, a cohort study of postmenopausal women with established CHD showed that higher saturated fatty acid (SFA) and lower polyunsaturated fatty acid (PUFA) intakes were associated with less progressive coronary atherosclerosis. These results directly contradicted earlier men-only studies that showed an increase in coronary atherosclerosis (Krauss et al., 2000). These new findings launched research into sex differences in basic metabolism and suggested that biological sex differences in how women and men process nutrients must also be taken into account in prevention strategies.

Gendered Model for Analyzing Mechansims Involved in Food Intake and Processing



The diagram above illustrates how researchers might analyze a three-way interaction between gender-related factors, sex-specific biology, and various biological mechanisms involved in human food intake and processing. Gender-related food intake is translated into different sex-specific base metabolisms, gene expressions, and dietary responses, thereby making nutrigenomics a pervasive Gendered Innovation. As such, it exemplifies the relationship between the Gendered Innovation (GI1) discussed above and Gendered Innovations 2a, 2b, and 2c discussed below.

a. Sex-Specific Metabolism

Serum metabolite concentrations allow a direct readout of biological processes: association of specific metabolomic signatures with complex diseases (such as Alzheimer's disease) and cardiovascular and metabolic disorders has been shown. Most studies, however, have not considered the role of sexual dimorphism. Mittelstrass et al. (2011) investigated sex-specific differences of serum metabolite concentrations and their underlying genetic determination. Investigators used more than 3,300 independent individuals from KORA F3 and F4 cohorts with measurement of 131 metabolites, including amino acids, phosphatidylcholines, sphingomyelins, acylcarnitines, and C6-sugars. A linear regression revealed significant concentration differences between men and women for 102 out of 131 metabolites. Sex-Specific Genome Wide Association Studies (GWAS) showed significant differences in beta-estimates for SNPs in the CPS1 locus for glycine. This study indicates that basic metabolite profiles of men and women are significantly different and, furthermore, that specific genetic variants in metabolism-related genes depict sexual dimorphism. Another study analyzing micro-array data of gene expression pointed to sexually dimorphic gene expression in somatic tissue, such as kidney or brain (Isensee et al., 2007). Both studies provide new, important insights into sex-specific differences of cell regulatory processes and underscore that studies should consider sex-specific effects in design and interpretation.

b. Sex-Specific Dietary Responses

Strong mechanistic evidence in support of sex differences in response to dietary intervention comes from animal models using omic-based technologies (e.g., transcriptomics, epigenomics, proteomics, and metabolomics). Studies using a rat model found sex-specific plasma protein responses to high-fat diets (Liu et al., 2012; Mukherjee et al., 2012). Another study using animal models found that a greater number of genes encoding myofibrillar proteins and glycolytic proteins were more strongly expressed in males than females when subjects were exposed to a high-fat diet (HFD), reflecting greater muscular activity and higher capacity for using glucose as an energy fuel. But a series of genes involved in oxidative metabolism and cellular defenses were more up-regulated in females than males (Oh et al., 2012). These results suggest that compared to males, females have greater fat clearing capacity in skeletal muscle through the activation of genes encoding enzymes for fat oxidation. Further clinical trials, using sex analysis, are needed to confirm these differences in women and men, but the initial findings suggest that analyzing sex could provide new insights.

c. Sex-Specific Nutrient Responses

Nutritionists using sex analysis have begun to explore—at the functional, mechanistic level—how nutrients affect gene expression and cell function in women and men. For instance, a recent study examined the interplay between inflammation-related genes and vitamin E. Data from a study in 500 elderly nursing home residents were used to examine vitamin E-gene interactions affecting the incidence of respiratory tract infections (RIs). The main finding suggested that the effect of vitamin E on reducing RIs depended on sex. Further research evaluating the effect of vitamin E on RIs should consider both genetic factors and sex, because both were found to have a significant (and interactive) bearing on the efficacy of vitamin E (Belisle et al., 2010).

Conclusions

NCDs now account for the majority of deaths worldwide. By integrating sex and gender analysis into a life course approach, researchers can explore the influence of sex-specific biological factors and gender-related social factors in determining the risk for NCDs. Specifically, analysis of high-risk behaviours indicates that gender attitudes and behaviours promote different patterns of healthy or unhealthy lifestyles among women and men. In addition, recent studies in nutrigenomics document that females and males respond differently to specific diets at the genetic, molecular, and cellular levels. Studies designed to incorporate both sex and gender analysis can provide rich data for designing interventions for healthy living—for researchers, policy makers, and the general public.

Next Steps

1. Information for observational studies (to correlate behavioural and dietary variables, for example) is generally obtained through questionnaires. More research is needed to learn whether women and men provide equally accurate data. Better knowledge of food consumption will allow researchers to better determine the effects of social environments on various populations and the sex-specific biological outcomes of different patterns of food consumption.
2. Randomized intervention studies designed to investigate female and male responses to specific diets need to include both women and men. Moreover, measurements should include potentially informative biomarkers provided by current omic technologies in addition to traditional risk factors.

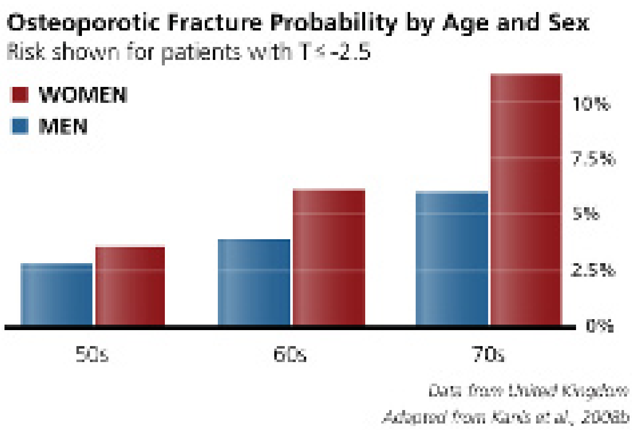
3. Studies exploring the effects of food consumption should be designed with two time frames in mind: chronic effects (i.e., long-term effects of diets on biomarkers and disease) and acute effects (i.e., postprandial fat challenges, known to be very different between men and women).

HEALTH & MEDICINE

Osteoporosis Research in Men: Rethinking Standards and Reference Models

The Challenge

Osteoporosis has been considered primarily a disease of postmenopausal women, an assumption that has shaped its screening, practice, diagnosis, and treatment (Klinge, 2010). This perception may exist because osteoporosis manifests about 10 years earlier in women than in men (see chart at right) and because women of all ages have higher risks of fracture than age-matched men (see chart below).



Although women have a higher fracture risk at a given age, medical outcomes of fractures are worse in men. A low-trauma ("fragility") fracture is associated with approximately twice the risk of a future fracture for a woman, but more than three times the risk for a man. As a result, the absolute risk of a subsequent fracture (per 100 patient-years) is similar in men (5.7%) and women (6.2%) (Center et al., 2007). In addition, a fragility fracture is associated with a twofold increase in mortality for a woman but a threefold increase for a man (Bliuc et al., 2009). These findings have led researchers to redefine osteoporosis as a disease affecting both women and men (see Method).

Osteoporosis in U.S. Women and Men

	WOMEN	MEN
Average Age of Onset	65 years	75 years
Lifetime Incidence of Osteoporotic Fracture	25%	13%
Fraction of Hip Fractures Due to Osteoporosis	70%	30%
Criteria Used to Diagnose	T ≤ -2.5 or Fragility Fracture	T ≤ -2.5 or Fragility Fracture

Data from Burge et al., 2007

Method: Rethinking Concepts

Osteoporosis has traditionally been defined as a disease of white, postmenopausal women. Men, however, account for nearly a third of osteoporosis-related hip fractures in Europe and the US, and it is becoming clear that they have been underdiagnosed because of the limited scope of diagnostic definitions (Amin, 2010). In 2002, the US Centers for Disease Control and Prevention (CDC) noted that, because of the lack of data, "there is no consensus at this time concerning the definition of low bone density in groups other than white women; however, it is clear that osteoporosis is not solely a disease of white women" (CDC, 2002). Redefining osteoporosis to include men as well as at-risk minority groups has led to new research and clinical practices that consider osteoporosis in broader populations.

Gendered Innovation 1: Male Reference Populations

Low bone mineral density (BMD) has long been recognized as an important predictor of fracture risk. Diagnostic criteria for osteoporosis were initially based on how many standard deviations a patient's BMD drops from the mean BMD of a female reference group, specifically young (aged 20-29 years) white women (CDC, 2002). The T-score is the standard deviation from the mean for this reference group. Negative T-scores indicate bone loss. Based on studies of women, a T-score of -2.5 (i.e., 2.5 S.D. below the mean for the reference group) has been defined as the diagnostic cutoff for osteoporosis (World Health Organization, 2003).

Between 1988 and 1994, the US CDC collected BMD data from more than 14,000 US women and men (National Center for Health Statistics, 1994). In 1997, a reference population of young men was used to calculate T-scores for male patients on the basis of healthy male (rather than healthy female) BMD values (Looker, 1997).

Calculating men's T-scores based on a male reference population greatly alters diagnosis rates. The prevalence of osteoporosis in men was estimated as 1%-4% using a female reference population; it has been estimated to be 3%-6% using a male reference population (Looker, 1997; Cummings, 2002). This practice marks an important gendered innovation (see Method).

Method: Rethinking Standards and Reference Models

When establishing reference models, researchers must consider:

1. **The Reference Population:** To what group of young, healthy people should a given patient be compared? Is it important that the patient be matched to a reference population of the same sex? The same ethnicity? Lifestyle? Geographic location?
2. **The Diagnostic Cutoff:** How many standard deviations below the mean of the reference population best diagnose osteoporosis?

In spite of these advances, problems persist. Diagnostic models based on BMD alone do not reliably predict who will suffer an osteoporotic fracture (Kanis et al., 2008a).

Is the T ≤ -2.5 Cutoff Appropriate for Male Patients?

The T ≤ -2.5 cutoff (using a male reference population) is a common diagnostic for osteoporosis in men. In a recent study of more than 7,000 men and women age 55 and older, 56% of non-vertebral fractures in women and 79% of non-vertebral fractures in men occurred in participants who were not diagnosed with osteoporosis according to the T ≤ -2.5 cutoff (Schuit et al., 2004). Moreover, there are concerns about the usefulness of T-scores in predicting fracture risk, especially in premenopausal women and men under age 50 (Leslie et al., 2006; Cummings, 2006).

Multiple international models for diagnosing osteoporosis have been established. The Canadian Medical Association, the United Kingdom's National Osteoporosis Guideline Group (NOGG) and Royal College of Physicians, and the German Dachverband Osteologie e.V. (DVO) each endorse different protocols for osteoporosis diagnosis (Papaioannou et al., 2010; Compston et al., 2008; Baum et al., 2008).

The Male Reference Model and Osteoporosis Intervention

Developing a male reference population represented a gendered innovation that led, in turn, to further clinical research, including:

1. **Considering Bone Health as an Integral Part of Men's Health.** Research is under way on possible lifestyle strategies for preventing osteoporosis in men, such as a healthy diet, physical activity, and not smoking tobacco (Pinheiro et al., 2009)—see Method below.
2. **Testing Pharmaceutical Treatments in Men.** Bisphosphonates, a class of anti-osteoporotic drugs, were evaluated two decades ago in postmenopausal women, but only recently in men (Francis, 2007). Including men in osteoporosis drug research may be important. Recent studies in postmenopausal women have called into question the benefits of long-

term (beyond 3-5 years) bisphosphonate therapy, and the FDA now recommends that "all patients on bisphosphonate therapy should have the need for continued therapy re-evaluated on a periodic basis" (Whitaker et al., 2012). More research is needed to understand the risks and benefits of specific dosing regimens in men and in pre-menopausal women (Giusti et al., 2010).

Method: Analyzing Factors Intersecting with Sex and Gender—Environment and Geographical Location (Differences among Men)

Significant differences exist between individuals of the same sex and, ostensibly, the same race. For example, widely used BMD reference values for white US men have proven inappropriate for white Danish men (Høiberg et al., 2007).

An important step toward more comprehensive diagnostic criteria is the US National Institutes of Health (NIH) Study of Osteoporotic Fractures in Men ("Mr. OS"), which began enrolling a cohort of 6,000 US men 65 years and older in 2000 and was extended to include large cohorts of men in China and in Sweden. In addition to examining the relation between BMD and fracture risk in men, Mr. OS examines factors—exercise level, diet, body composition, tobacco use, and alcohol—that often correlate with sex, race, and ethnicity (Bennett, 2004; Cauley et al., 2005).

Ancestry, Ethnicity, and Geography

For patients of a given sex, factors such as ancestry and ethnicity should also be considered in establishing reference populations. In the U. S., significant differences are seen in fracture risk between women of different self-reported races. Although African American women have lower fracture rates than white women (48% lower risk), black women have higher mortality after hip fracture than do white women. Reasons may include socioeconomic disparities, unequal access to treatment, and prevalence of other diseases (Thomas, 2007)—see Method.

Method: Analyzing Gender—Physical Activity (Differences among Women)

Biologist Anne Fausto-Sterling has described how environment and experience can "shape the very bones that support us." Osteoporosis is a complex disease that emerges over the life cycle as a response to "specific lived lives" (Fausto-Sterling, 2008). Gender roles interact with sex in determining bone strength: In Europe and the US, adolescent girls may exercise less than boys. Along with biological factors, these gendered behaviours result in girls laying down less bone than boys in their teens. In addition, occupational divisions of labor mean that men are more likely than women to do heavy physical work, such as construction (Fausto-Sterling, 2005). And older women are generally less physically active than their male counterparts; inactivity may contribute to bone loss and increase fracture risk.

Gendered Innovation 2: New Diagnostics Based on Secondary Contributors to Osteoporosis and Metabolic Bone Disorders (SECOBs)

Researchers studying differences both between and within groups of women and men have identified secondary contributors to osteoporosis and metabolic bone disorders (SECOBs), medical conditions, and treatments that increase the risk of osteoporotic fracture. Understanding SECOBs is especially important in estimating men's fracture risk; men with fragility fractures are more likely than women to have previously diagnosed SECOBs, and when patients are screened after a fracture, new SECOBs are more often found in men (50%) than in women (32%) (Ryan et al., 2011; Tannenbaum et al., 2002). New diagnostics include FRAX, Garvan Fracture Risk Calculator (GFRC), and QFracture, among others (Gimeno, 2010) (see Gendered Innovations website for details). Clinicians continue to debate the relative advantages and disadvantages of the FRAX, GFRC, and QFracture systems, all of which can be used to estimate a patient's risk of osteoporotic fracture over the next ten years (Bolland et al., 2011; Bennett et al., 2010).

Conclusions

Osteoporosis has been reconceptualized as affecting both women and men. This Gendered Innovation led to the development of male reference populations, allowing for better evaluation of fracture risk in men. BMD alone, however, is not a good predictor of fracture in women or men. New diagnostics, such as FRAX, GFRC, and QFracture, may predict a patient's fracture risk more accurately than BMD alone by analyzing factors intersecting with sex and gender.

Next Steps

1. **Use gender analysis to optimize osteoporosis prevention.** Many risk factors and protective factors are gendered. A prevention campaign might focus on increasing physical activity and on smoking cessation, recognizing that women are more likely to be physically inactive and men are more likely to smoke tobacco.
2. **Develop reference models focused on how fracture risk is influenced by biological sex and gendered behaviours.** The US Preventive Services Task Force has concluded that "evidence is lacking, of poor quality, or conflicting" regarding osteoporosis screening for men" (USPSTF, 2011). Current European guidelines for the diagnosis and management of osteoporosis recommend evaluating men's fracture risk according to diagnostic thresholds developed to predict fracture risk in postmenopausal women (Kanis, 2008b).
3. **Work to educate the public about the true incidence of the disease and to promote bone-healthy lifestyles in women and men (NIH, 2010).** The NIH has determined through surveys that a majority of American men view osteoporosis as a "woman's disease." Correcting this inaccurate view is important. The gendered beliefs of physicians may also contribute to the perception that osteoporosis is a woman's disease, resulting in osteoporosis in men being "substantially underdiagnosed, undertreated, and underreported" (Qaseem et al., 2008; Geusens et al., 2007).

TRANSPORT

Public Transportation: Rethinking Concepts and Theories

The Challenge

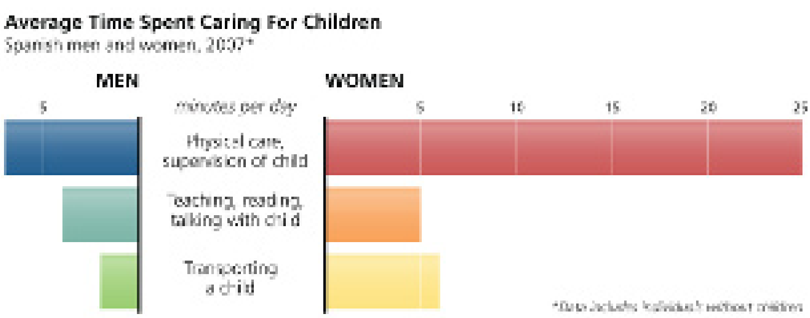
Researchers examining public transportation often categorize trips according to purpose in order to better understand existing transportation patterns and to better plan for infrastructure changes. For example, the US Federal Highway Administration uses the following categories for public transit (US FHA, 2009):

To/From Work
Work-Related Business
Shopping
Other Family/Personal Errands
School/Church
Social and Recreational
Other

Categories used in transportation surveys—and, hence, the way statistics are gathered and analyzed—may not properly account for caring work, i.e., unpaid labor performed by adults for children or other dependents, including labor related to the upkeep of a household.

Gendered Innovation 1: Visualizing the Mobility of Care

Time Use Surveys provide a perspective for evaluating transportation surveys. The Harmonised European Time Use Survey codes time use into forty-nine categories and provides sex-disaggregated data on time usage within fifteen countries. In Spain, women spend more time than men performing the three explicit categories of childcare coded in the Survey.



Data for Spain are similar to data averaged across the EU; in the 15 countries surveyed, women performed an average of 32 minutes of childcare per day, and men performed an average of 12 minutes. In all EU countries surveyed, women spent significantly more time performing childcare than men—from 1.7 times more in Sweden to 4.8 times more in Latvia. This pattern holds in the US as well—in 2010, the average US woman spent 32 minutes caring for and helping children in her household, twice as much as the average US man's 16 minutes (United States Bureau of Labor Statistics, 2011). It is important to recognize that men's caring work has increased over time. Care-giving among British fathers, for example, increased nine-fold from 1961 to 1999 (O'Brien et al., 2003).

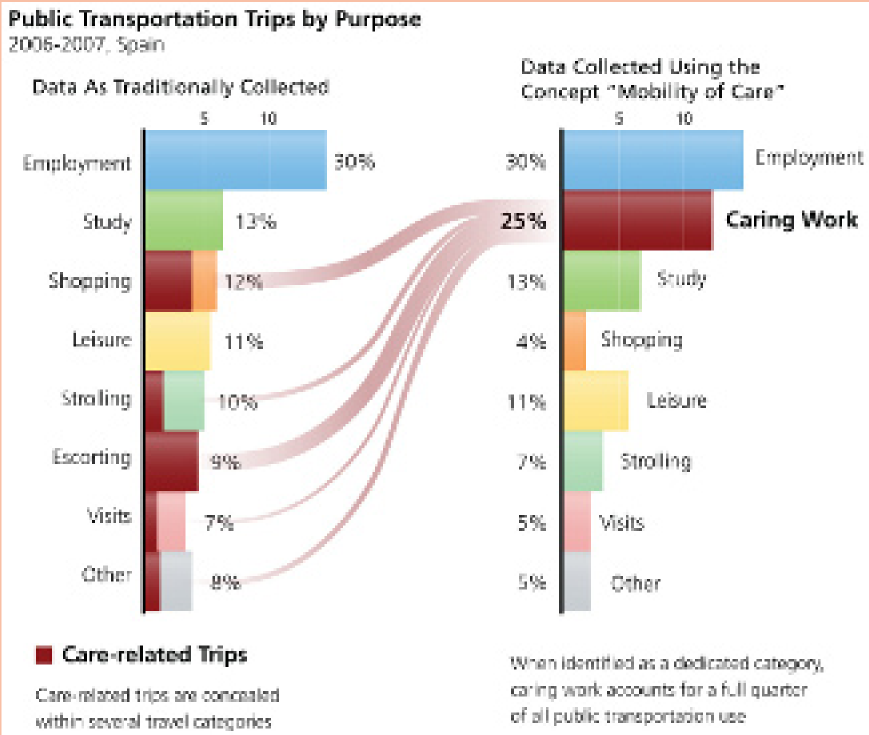
That women spend significantly more time than men performing caring work implies that consideration of caring work is a key to gender equality in transportation; many forms of caring work rely on public transportation.

Inés Sánchez de Madariaga's innovative concept, "mobility of care," provides a perspective for "recognizing and revaluing care work"—to appreciate the trips that women and men make when caring for others (Sánchez de Madariaga, 2009). Adding this concept to transportation surveys facilitates designing these trips into transit systems—see Method.

Method: Rethinking Language and Visual Representations

The innovative concept "mobility of care" reveals significant travel patterns otherwise concealed in data collection variables (Sánchez de Madariaga, 2012; Sánchez de Madariaga, 2009). The charts below represent public transportation trips made in Spain in 2007. The first chart (left) graphs transportation data as traditionally collected and reported. It privileges paid employment by presenting it as a single, large category. Caring work (shown in red) is divided into numerous small categories and hidden under other headings, such as escorting, shopping, and leisure.

The second chart (right) reconceptualizes public transportation trips by collecting care trips into one category. Visualizing care trips in one dedicated category recognizes the importance of caring work and allows transportation engineers to design systems that work well for all segments of the population, improve urban efficiency, and guard against global warming (Sánchez de Madariaga, 2011).



A number of innovations in transportation design have been implemented to support the mobility of care. In London, for example, these include:

- Step-free access to trains, subways, and buses. Transportation authorities are removing steps from streets to platforms to accommodate baby carriages, luggage, wheelchairs, and similar devices. By 2007, the London Underground had developed 47 step-free stations.
- Wide aisle gate access to transportation.
- Level access from platforms to trains (Transport for London, 2007).

Gendered Innovation 2: Conceptualizing and Studying Trip Chaining

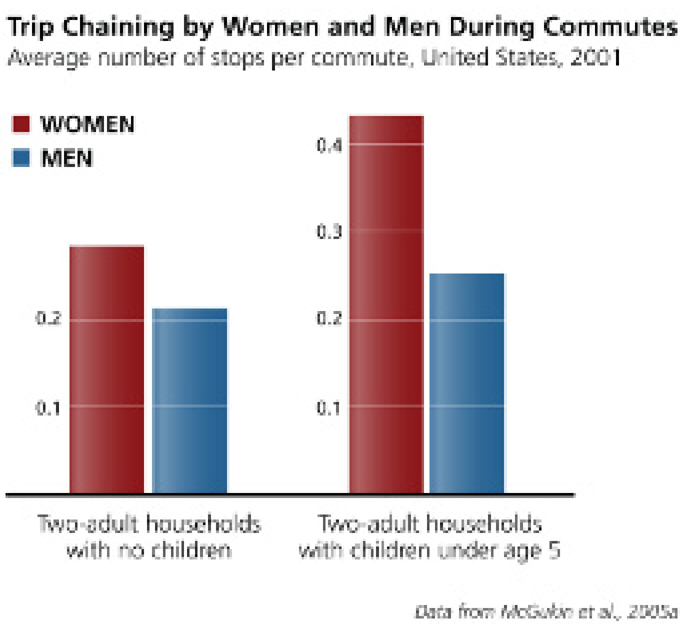
A simplistic definition of a "trip" describes each trip as a journey from a single starting location to a single destination, typically using a single form of transportation. The concepts of "trip chaining" and "multipurpose trips" expand on this definition by recognizing that trips often involve a sequence of destinations and are multimodal (McGuckin et al., 2005b; Hanson, 1980). Research on trip chaining has examined the directions of trips, timing of travel, and purpose of the stops with attention to gender and other factors intersecting with sex and gender—see Methods below.

Method: Rethinking Concepts and Theories

Analyzing gender in transportation requires challenging underlying concepts and identifying gaps in the way data are collected. It also requires introducing new concepts and theories that model the complex routes taken by real people. A study of travel in the United States between 1995 and 2001 using the concept of trip chaining has produced the following insights regarding women's and men's travel patterns:

- A greater number of women than men make multiple-stop trips when traveling between their homes and workplaces. This difference between women and men is decreasing, however, mainly as a result of an increase in trip chaining among men (between 1995 and 2001, the number of stops men made while returning home from work increased by 24%).
- Women make more short stops on the way to or from work than do men to perform household-sustaining activities, such as shopping and family errands, and working women in two-worker families were twice as likely as men in two-worker families to pick up and drop off school-age children at school during their commute.
- Other demographic variables interact with gender in predicting trip chaining. For example, having a child under age 5 increases trip chaining by 54% for working women and 19% for working men—see chart (McGuckin et al., 2005a).

Research on trip chaining—with attention to gendered differences in travel—has been the key to urban development in Vienna, for example. When planning extensions to subway lines, civil engineers considered multi-destination trips involving travel to workplaces, crèches, schools, hospitals, and parks (Irschik, 2008).



Gendered Innovation 3: Gathering Sex-Disaggregated Data Improves Transportation Research and Policy

In 2001, officials in the Swedish Transportation Department acknowledged disparities between women and men in transportation sector employment (for example, most people in leadership positions were men, a form of vertical segregation) and proposed integrating gender analysis into Swedish transportation policy and administration practices (Sahlin et al., 2001). To advance the goal of creating "a gender-equal road transport system [...] that is designed to fulfill the transport needs of both women and men," researchers disaggregated transportation data by sex. Researchers found that, among people in paid employment, a greater proportion of women (18%) than men (14%) use public transit. Other differences were also observed.

Subsequently, in planning a new commuter route project in Skåne (Sweden's southernmost province), planners "prioritized routes that contributed to strengthening and developing local labour market regions for women, as these regions are geographically smaller, ahead of routes that expand the wider geographical labour market regions for men" (Swedish Road Administration, 2009). The Swedish Road Administration has also highlighted the need for a transit system to support gender equality, and its considerations include the reality that women "take more responsibility [than do men] for household work and caring for the young and elderly" (Swedish Road Administration, 2010).

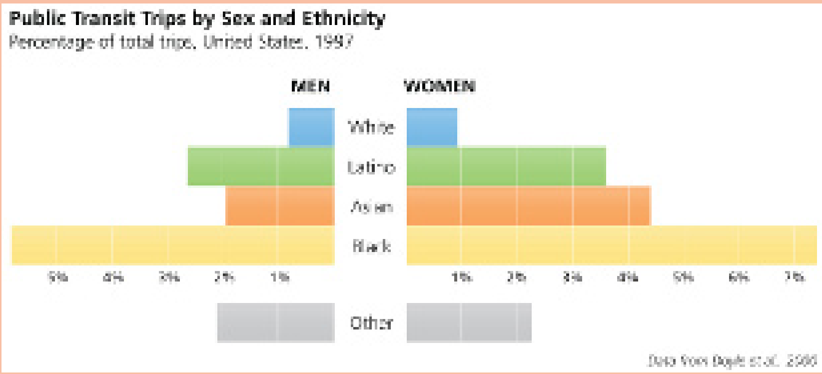
Multiple EU projects funded under the EU FP7 use sex and gender analysis to enhance research. For example, the EU FP7 Transport Needs for an Ageing Society (TRACY) project gives "special attention to the gendered nature" of older people's transport needs (Gather et al., 2011).

Method: Analyzing Factors Intersecting with Sex and Gender

Disaggregating data by sex is a first step. To serve a wide user base, other variables need to be considered and analyzed for how they interact with sex and gender (Audirac, 2008). These include:

- Age: Designing public transport systems to consider the mobility needs of older adults supports safe mobility for older people who have ceased driving for various health reasons (Currie et al., 2010). Gender also interacts with age in the context of driving cessation: researchers found that "older females were more likely than males to have planned ahead [for cessation], made the decision themselves, and stopped at appropriate times" (Oxley et al., 2011). The correlation between age and geographic location is a serious challenge in supporting the mobility of older people; more older people live in rural areas than do younger people (O'Neill, 2010).

- **Family status:** The presence of children—particularly young children—increases the number of caring trips and the need for routes to accommodate these needs (Crane, 2007).
- **Ethnicity:** In the United States, use of public transportation differs by both sex and self-reported ethnicity. In all ethnic groups, women make a larger proportion of their trips via public transportation than do men. These sex differences, however, vary by ethnicity—see chart (Doyle et al., 2000).



- **Geographic location:** Locations differ in safety. New design features have made transportation safer. These include designated waiting areas, transparent bus shelters, emergency intercoms and surveillance mechanisms, and alternative services and routes, such as request-stop programs, that allow nighttime users to disembark from the bus at locations closer to their final destination (Schulz et al., 1996).

Researchers working on the EU FP7 Growing Older, stAying mobiLe: The transport needs of an ageing society (GOAL) project have created profiles of older people by analyzing gender alongside other factors, including demographic variables (age, financial resources, employment, etc.) and patterns of transit usage (Hoedemaeker et al., 2012).

Conclusions

Analyzing gender in public transportation requires:

1. Rethinking categories used in public transportation surveys. The innovative concept "mobility of care" captures significant travel patterns, and it can be used to render public transportation more equitable and responsive to users' needs.
2. Rethinking basic concepts, such as what constitutes a "trip"—whether to a single destination or a series of "chained" destinations.
3. Gathering data disaggregated by sex and other variables (such as income, self-reported ethnicity, family status, etc.) that may correlate with public transit use.

Next Steps

The European Commission and other governmental organizations have identified how sex and gender analysis can enhance public transportation through both basic research and policy-making:

Basic Research:

1. Analyzing biological sex differences (in women's and men's height, weight, etc.) in designing steps and railings, positioning buttons, and other use factors. This analysis includes rethinking standards and reference models as necessary to recognize pregnancy as a normal physiological state (European Commission, 2007).
2. Collecting sex-disaggregated transportation data and including factors intersecting with sex and gender (such as "socioeconomic and demographic indicators") in data analysis (European Commission, 2007).

Transport Policy:

1. Working to eliminate disparities between women's and men's representation on transit planning boards through efforts to increase the number of women experts in the transit work programme (European Commission, 2007).
2. Conducting regular and systematic "gender audits" to evaluate transport systems from a gender perspective (Hamilton et al., 2000).
3. Harmonizing transportation and time use statistics within the European Union in order to account for the mobility of care (European Parliament's Committee on Transport and Tourism, 2006).

ANNEX C: Methods of Sex & Gender Analysis

The Gendered Innovations website presents state-of-the-art methods of sex and gender analysis. This section presents general methodology; methods are applied in each case study (as noted below).

Rethinking Research Priorities and Outcomes

Researchers and engineers, their senior staff, and other stakeholders make strategic decisions about what work to undertake: They set priorities for future research. This method discusses how to address the potential implications of strategic choices in terms of sex or gender.

A number of factors influence how researchers and engineers think about their research and development priorities, all of which may raise sex- and gender-related issues. These factors include:

- initiatives of public and private funders and other stakeholders
- industrial funding and lobbying
- military funding priorities and lobbying
- health funding priorities and lobbying
- regulatory environment
- market research on competitors or particular market segments
- the configuration of academic disciplines
- professional career tracks and standards for promotion
- political and cultural initiatives and movements
- a desire to solve social problems
- personal experience and interests
- beliefs and unconscious assumptions

Critical questions for analyzing the significance (if any) of sex and gender:

1 **How do gender norms influence priorities?** What concerns about sex and gender have guided the priorities chosen, and how might they shape or limit the agenda (Schiebinger et al., 2010)?

   a. What are the benefits and drawbacks of the research or development in terms of its potential impact on gender equality? For instance, there is an impact on gender equality if assistive technologies serve men more than women. The historic male default in speech synthesis—a bias that was likely unconscious and may have arisen as a result of most professionals in related fields being men—meant that women in need of speaking aid had no female voices to choose from (see Case Study: Making Machines Talk).

b. What gender norms or gender relations will be challenged or reinforced by a particular line of inquiry or development (Oudshoorn 1994)? For example, when software developers produce "pink" games (such as *Barbie Fashion Designer*) for girls, they may inadvertently reinforce gendered stereotypes about girls' and women's interests. Creating separate "blue" and "pink" games for boys and girls reinforces gender essentialism and may not be a productive strategy: as of 2007, the most widely played game among young adults ages 12–17, *Guitar Hero*, enjoyed nearly an even balance of young women and young men players (see Case Study: Video Games).

c. What is overlooked when research or development work is guided by gender assumptions rather than evidence? Are researchers missing opportunities for fruitful innovation? For example, sex determination research historically focused on testis determination and overlooked the genetics of ovarian development (see Case Study: Genetics of Sex Determination).

2. **Whom will the research benefit, and whom will it leave out?** Will the research or technological development have differential effects on women and men, or on particular groups of women and men (Harding, 1991; Oudshoorn et al., 2002; IOM, 2010)? For example, assistive technologies have the potential to help the elderly remain independent; designers should take into account that the majority of the elderly and of elder care givers are women (see Case Study: Exploring Markets for Assistive Technologies for the Elderly).

   a. Does research or technology need to differentiate between women and men? If so, which specific women or men (such as urban vs. rural, old vs. young)? What gender norms, relations, or identities are relevant to these groups?

   b. Are there issues related to biological sex that might be relevant?

3. **Do established practices and priorities of the funding agency encourage Gendered Innovations?** A number of granting agencies now require that potential grantees consider whether, and in what sense, sex and gender are relevant to the objectives and methods of the proposed research (see Gendered Innovations website: Policy Recommendations, Major Granting Agencies).

   a. Does bringing sex and gender analysis to research or technology meet previously unmet needs or open new markets? For example, heart disease has long been considered a male disease and "evidence-based" diagnostic tests, treatments, and clinical standards are based on the most common presentation and pathophysiology in men. Yet heart disease is a major killer of women as well. Addressing heart disease in women has required changes in research priorities and has led to numerous insights (see Case Study: Heart Disease in Women).

   b. What potential opportunities are researchers missing by *not* considering sex or gender? For example, seatbelts can harm fetuses even in low-impact automobile collisions. Engineers have missed the opportunity to design a seatbelt that provides safety also for pregnant women. Doing so may open a new market in addition to meeting the safety needs of fetuses.

   c. Are these missed opportunities undermining the sponsoring agency's mission?

4. Are new data required to make decisions about funding priorities?

a. What do sponsors need to know in order to make evidence-based judgments about integrating sex or gender into research and development priorities? What evidence is already available? What data need to be collected? For example, data are needed to understand whether creating video games aimed at young women is an effective strategy for increasing women's representation in information technology employment (see Case Study: Video Games).

Related Case Studies

Climate Change

Genetics of Sex Determination

HIV Microbicides

Human Thorax Model

Information for Air Travelers

Making Machines Talk

Nanotechnology-Based Screening for HPV

Pregnant Crash Test Dummies

Rethinking Concepts and Theories

Theories provide a framework for explaining and predicting phenomena. *Concepts* relate to how data are described and interpreted, including how particular phenomena are categorized. Some theories concern a whole field and carry the status of a paradigm; others concern a few questions or topics within the field. In either case, theories and concepts frame how research is conducted within a particular field or topic area, influencing:

> "We have terms and concepts that drive our thinking. Concepts, such as 'sex hormones' and the 'default female pathway' in the genetics of sex determination, send research down the wrong path." Stanford biologist

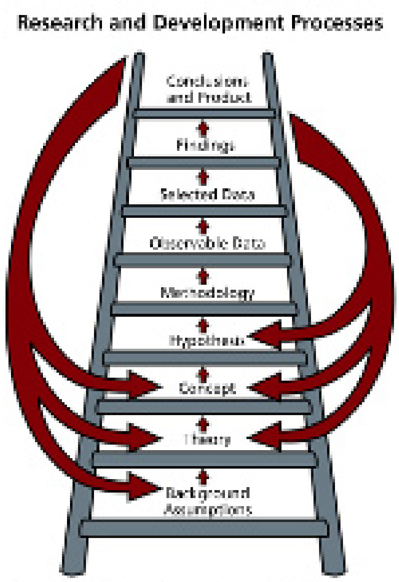
- what constitutes an interesting research topic
- what needs explanation (i.e., interesting research questions)
- what counts as evidence
- how evidence is interpreted (including concepts used)
- what methods are considered appropriate

The point of rethinking central concepts and theories in relation to sex and gender is to ensure:

1. that any assumptions made or issues addressed are based on the best available evidence and information, and
2. that the concepts and theories adopted do not blind researchers to important aspects of sex and gender that could be a fertile source for innovation.

Questions:

1. What (if any) "background assumptions" about sex and gender are shaping or embedded in the concepts and theories of the field? These may not be explicit. Background assumptions are shared preconceptions and practices within a research community that go unquestioned (Longino, 2002). Analyzing Gender assumptions and Analyzing Language and Visual Representations may help to uncover unconscious assumptions that inform concepts and theories.
2. What are the implications of concepts and theories about sex and gender for how research is conducted in the field—that is, the choice of research topics, the methods used, what counts as evidence, and how it is interpreted? How do these concepts and theories contribute to Formulating Research Questions?



The relationship between evidence, concepts, and theories is never [illegible]

3. What issues related to sex and gender are *not* being addressed, or are being misunderstood or misrepresented, as a result of how concepts and theories are framed in the field? For example, the concept of the "out-of-position driver" rules out certain people as part of the population for whom engineers design (see Case Study: Pregnant Crash Test Dummies).
4. Are there conflicts between the assumptions being made about sex and gender (within existing concepts and theories in the field) and relevant available evidence and understandings about sex and gender? How do concepts and theories need to be reformulated to take this new evidence into account?
5. How do new concepts or theories bring to light new evidence?
6. Do these concepts and theories open up spaces for Gendered Innovations?

Example of essential concept and theory change: Initially, archeologists designated only certain stone objects, such as finely articulated arrowheads, spears, hand axes, and the like, as "tools." This categorization led theorists to see early human societies as sustained by big-game hunting. In a second step, it was presumed (drawing on contemporary norms) that men were the toolmakers and hunters. When the concept of "tools" was opened up to include flake stone tools used in nutting, leatherworking, grain harvesting, and woodworking, theorists better understood the broad range of food production in early human societies. Expanding notions of what items count as "tools" in prehistoric societies opened new questions about what early people usually ate, and about the economic and cultural goals of tool-making societies (Conkey, 2007; Gero, 1993).

Example of essential concept change: Osteoporosis has traditionally been defined as a disease of white, postmenopausal women. Men, however, account for nearly a third of osteoporosis-related hip fractures in Europe and the US, and it is becoming clear that they have been underdiagnosed because of the limited scope of diagnostic definitions. Redefining osteoporosis to include men as well as at-risk minority groups has led to new research and clinical practices that address osteoporosis in broader populations (see Case Study: Osteoporosis Research in Men). In contrast, heart disease has been defined as a disease of middle-aged men. Yet heart disease is also a major killer of women. Redefining heart disease to include women has required redefining heart disease symptoms and identifying new diagnostic tools; it may also require redefining populations used in clinical trials away from the traditional 70% men and 30% women (see Case Study: Heart Disease in Women).

Related Case Studies

Genetics of Sex Determination

Heart Disease in Women

Osteoporosis Research in Men

Public Transportation

Textbooks

Formulating Research Questions

Research questions typically flow from research priorities (see Method: Rethinking Research Priorities and Outcomes) and from the theories and concepts that frame research (see Method: Rethinking Concepts and Theories). Research priorities—along with concepts and theories—directly influence how research is designed. They function to

1. delimit questions asked—and, by implication, questions not asked (see, for example, Case Study: Genetics of Sex Determination).
2. frame the research design and choice of methods.

As with other stages of the research and development processes, the choice of a research question is often underpinned by assumptions—both implicit and explicit—about sex and gender (see Method: Analyzing Gender). As in other stages of research and development, potential for creative innovation lies in critically examining existing practices in light of available evidence about sex and gender (Bührer et al., 2006; Schraudner et al., 2006; Schiebinger, 2008; Wylie et al., Klinge, 2010; IOM, 2010; Wajcman, 2010).

Critical questions for analyzing the significance (if any) of sex and gender in formulating research questions:

1. What is the current state of knowledge of sex and gender (norms, identities, or relations) in a given area of research or development?
2. What do we *not* know as a result of not analyzing sex and gender?
3. How have sex and gender functioned to limit the research questions posed in this field? For example, coronary angiography is a powerful diagnostic tool for assessing coronary artery disease, but it can cause bleeding complications, especially in women. Researchers asked

how angiography could be made safer and then designed and patented new catheters and procedures to allow angiography from the radial artery rather than the groin. This shift reduces bleeding in both women and men (see Case Study: Heart Disease in Women).

4. Have assumptions been made about sex and gender? Are these justified in light of available evidence? Are assumptions underpinning the research questions invalid when subjected to critical analysis? For example, cultural assumptions about gender difference can lead companies to market "gender-specific" products—in one case a sex-specific knee prosthesis—that may not be the best choice for consumers (see Case Study: De-Gendering the Knee).
5. Have any potentially relevant groups of research subjects been left out (e.g., female animals in animal research, men in osteoporosis research, pregnant women in automotive engineering)? (See Case Studies: Animal Research, Osteoporosis Research in Men, and Pregnant Crash Test Dummies.)
6. What research questions would lead to more robust research designs and methods? For example, in studies of sexual differentiation, geneticists have revealed the shortcomings of scientific models that portrayed the female developmental pathway as "passive." By challenging assumptions of passivity, researchers formulated new questions about the ovarian developmental pathway. New findings now suggest that both female and male development are active, gene-mediated processes (see Case Study: Genetics of Sex Determination).

Related Case Studies

Genetics of Sex Determination

Stem Cells

Heart Disease in Women

HIV Microbicides

Human Thorax Model

Analyzing Sex

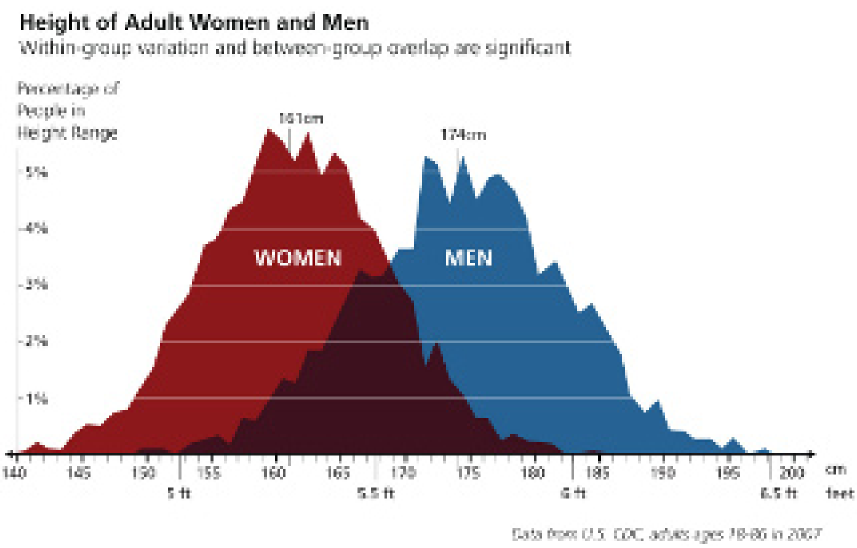
Sex, the biological basis of female and male distinctions (see Term: Sex), is an important variable to consider when setting research priorities, developing hypotheses, formulating study designs (see also Methods: Rethinking Research Priorities and Outcomes; Rethinking Concepts and Theories; Designing Biomedical Research; and Engineering Innovation Processes).

Sex is a fundamental variable in all biomedical research and a prime consideration for product and systems design. Analyzing sex is important, but sex should not be over overemphasized (see Term: Overemphasizing sex differences as a problem).

In biomedical research, sex may need to be analyzed—in human and animal research subjects, and in organs, tissues, cells, and their components (IOM, 2012; Beery et al., 2011; Wizemann et al., 2001). In engineering, sex may need to be analyzed at the levels of physiology and biomechanics of users, in both product and systems design (see Method: Analyzing Standards and Reference Models).

Analyzing sex involves six steps:

1. **Reporting the sex of research subjects or users.** This is a prerequisite to sex analysis. Some granting agencies and peer-reviewed journals require reporting sex—for human, animal, and (where appropriate) organ, tissue, and cell research (see Gendered Innovations website: Policy Recommendations, Peer-Reviewed Journals). Reporting the sex of the research subject or considering the sex of the user/customer is important even in single-sex studies to allow meta-analysis, identify research gaps, and prevent over-generalizing findings beyond the sex studied (see Case Study: Stem Cells).
2. **Recognizing differences that exist *within* groups of females and males/women and men.** Both biological and sociocultural factors differ substantially among individuals within each sex over their respective lives. They include profound changes associated with reproductive biology (such as occur at puberty and, in women, throughout the menstrual cycle, during pregnancy, and at menopause) and with aging. Take, for example, height. In the US, women are shorter than men on average, but about 3% of women are taller than the average man, and 6% of men are shorter than the average woman. The height difference between the average woman and man is less than the height difference between a 90th percentile woman and a 10th percentile woman, or the difference between 90th and 10th percentile men (see chart; see also Case Studies: Human Thorax Model; Pregnant Crash Test Dummies).



3. **Collecting and reporting data on factors intersecting with sex in study subjects or users/consumers.** Women and men (females and males) may differ by age, lifestyle (e.g., diet, physical activity, and use of tobacco, alcohol, and other drugs), socioeconomic status, and other gendered behaviours and variables (see Method: Analyzing Factors Intersecting with Sex and Gender). Efforts should be made to "match" female and male cohorts according to variables that might influence interpretation of study findings (see Method: Designing Health & Biomedical Research). For example, in the development of prostheses for total knee arthroplasty, overlooking intersecting factors led to a focus on sex that did not improve patient outcomes (see Term: Overemphasizing Sex Differences as a Problem).

Prosthesis designers observed statistically significant differences between women and men's knee anatomy and produced a "gendered knee," which was marketed to women patients. Although biological sex does give rise to differences in knee anatomy, sex may not be the principal factor for prosthesis selection—in this case, height is a more important variable for matching patients to prostheses (see Case Study: De-Gendering the Knee).

4. **Analyzing and reporting results by sex.** Sex-specific analyses should be conducted and the findings reported. For example, women and men may require different airbag inflation energies, or different dosages of a drug to produce a given effect, because of differences in body size and composition. Adjusting the data for baseline differences and factors that intersect with sex is a crucial step in understanding the sex difference observed. For example, researchers who analyzed sex in studies of cardiovascular disease identified sex differences in arterial plaque formation: women tend to develop diffuse plaques, whereas men develop localized plaques (von Mering et al., 2004). This difference has ramifications for the design of stents (see Case Study: Heart Disease in Women).
5. **Reporting null findings.** Researchers should report when sex differences (main or interaction effects) are not detected in their analyses to reduce publication bias, an important consideration in meta-analyses (IOM, 2012). Where relevant, researchers should note when data regarding sex differences are statistically inconclusive, especially in the context of factors intersecting with sex. Statistical power may be limited in cases where it is difficult to recruit patients of one sex, for example.
6. **Meta-Analysis.** Good design and clear reporting may enable cross-study analysis. Combining data from multiple studies can increase statistical power, but it can also compound error, especially if factors intersecting with sex and gender are overlooked (Blauwet et al., 2007; Bailey, 2007).

Related Case Studies

Animal Research

Genetics of Sex Determination

Environmental Chemicals

Exploring Markets for Assistive Technology for the Elderly

Heart Disease in Women

Making Machines Talk

Nutrigenomics

Pregnant Crash Test Dummies

Stem Cells

Analyzing Gender

Gender comes into play when cultural attitudes are important to a project (see Term: Gender). This method looks specifically at:

1. **Researchers' and engineers'** gender assumptions and behaviours as these relate to the proposed research.

2. **Research Subjects' and Users'** gender needs, assumptions, and behaviours as these relate to the proposed research.
3. **How #1 & #2 interact**—or gender relations between researchers/engineers and subjects/users.

Gender attitudes and behaviours "reside" and are (re)produced at various levels—in individuals, social institutions, and wider society and cultures. This method assumes that researchers can begin to learn how gender functions. The value of its implementation depends, as with other research methods, on the skill and creativity of the research team.

Gender is a primary linguistic, cognitive, and analytical category in science, health & medicine, and engineering (Schiebinger, 2008; Klinge et al., 2010; Zorn et. al, 2007; Bührer et al., 2006; Oudshoorn et al., 2003; Strum et al., 2000). Yet gender assumptions often go unquestioned and hence remain invisible to a scientific community (Schiebinger, 1989; Oudshoorn, 1994; Richardson, 2013). These background assumptions unconsciously influence scientific priorities, research questions, and choices of methods (see also Methods: Rethinking Research Priorities and Outcomes, Rethinking Concepts and Theories, and Formulating Research Questions). When gender assumptions are invisible and remain unexamined, they may introduce bias into science and engineering. They can undermine the "self-correcting" mechanisms in research and design.

1. **What are the researchers' or engineers' gendered assumptions and behaviours that affect the proposed research?**
   A. Do background assumptions—or "taken-for-granteds"—in the research community affect research in unexamined ways? Take, for example, the genetics of sex determination. For decades the study of sex determination focused on "testis determination." The ovary-producing female pathway was considered a passive, "default" pathway. New models of sex determination show both female and male development as parallel, active, gene-mediated processes (see Case Study: Genetics of Sex Determination).
   B. What background assumptions have influenced choices about research subjects or users? For example, basic research in animals has focused on males largely because researchers assume that males are less variable (see Case Study: Animal Research).
   C. What unexamined assumptions have researchers made about women/men (or females/males of other species) in their research? When they consider men, do they consider which men? Are these poor men, wealthy men, fit men, poorly-educated men (see also Method: Analyzing Factors Intersecting with Sex and Gender)? Not all men (or women) are the same. To avoid stereotypes, researchers should identify their subjects/users specifically. For example, HIV microbicides have been added to vaginal gels. In addition to delivering microbicides (contraceptives or other products), gels also act as lubricants—which may make them undesirable to some potential users (see Case Study: HIV Microbicides).
   D. How do gender divisions of labor affect a project? What former blind spots may prove fertile areas for innovation? For example, researchers who studied divisions of labor in service call centers found that most employees with direct contact to customers were women (Russell, 2008). These women typically used software based on managers' assessments of their needs and not on direct study of their work flow. Engineers who observed how these women worked were able to redesign software in ways that ultimately boosted productivity (Maass et al., 2007).

2. **What are the research subjects' and users' gender needs, assumptions, or behaviours as they affect the proposed research?**
   A. Do men and women have differing needs and expectations for outcomes?
   B. What are the actual characteristics of subjects and users, what are the self-reported characteristics, and how might they be influenced by stereotypes? For example, understanding the characteristics of elderly populations is crucial to designing successful assistive technologies. While elderly women and men often have similar needs, understanding how sex and gender interact to impact aging can assist engineers develop technologies that best fit user needs (see Case Study: Exploring Markets for Assistive Technology for the Elderly).
3. **How do #1 & #2 interact? How do the genders of the researcher and the genders of the research subject/user interact?**
   A. How might a subject respond differently to a man researcher or a woman researcher? For example, in a telephone interview, the perceived sex of the interviewer may influence the responses of research subjects. This effect may be different for women subjects and men subjects, reflecting interactions between researchers' and subjects' gender attitudes (Kane et al., 1993). Similar effects may also related to researchers' and research subjects' race and ethnicity (Streb et al., 2008).
   B. What scope is there for the groups concerned to be involved in the research? For instance, the expertise held by particular groups of women or men might be usefully accessed for gendered innovations (see also Method: Participatory Research and Design). For example, because water procurement is women's work in some societies, many women have detailed knowledge of soils and their water yields. Tapping into this knowledge is vital to civil engineering and development projects—for instance, in determining where to place wells and water taps (see Case Study: Water Infrastructure).

Related Case Studies

Climate Change

Exploring Markets for Assistive Technology for the Elderly

Heart Disease in Women

Making Machines Talk

Osteoporosis Research in Men

Public Transportation

Video Games

Water Infrastructure

Analyzing Factors Intersecting with Sex and Gender

It is important to analyze sex and gender (see Method: Analyzing Sex; Analyzing Gender), but examining how other factors intersect with sex and gender is also necessary (Hankivsky et al., 2008). These factors or variables can be biological, socio-cultural, or psychological aspects of users, customers, experimental subjects, or cells. These factors include but are not limited to:

- Genetics
- Age
- Sex Hormones
- Reproductive Status
- Body Composition
- Comorbidities
- Body Size
- Disabilities
- Ethnicity
- Nationality
- Geographic Location
- Socioeconomic Status
- Educational Background
- Sexual Orientation
- Religion
- Lifestyle
- Language
- Family Configuration
- Environment

Researchers can investigate how sex and/or gender intersect with other significant factors by:

1. **Identifying relevant factors or variables.** Before beginning a study, researchers should hypothesize relevant factors. Sex and gender intersect with other biological and social variables to produce between- or within-group differences (Whittle et al., 2001). Those factors may reveal sub-group differences among women and among men that would have been obscured by using only gender or sex as a variable (see Case Study: Nutrigenomics). Accounting for differences in socioeconomic status, for example, may reveal unexpected differences between women and men that cannot be explained by gender or socioeconomic status alone, such as women of high socioeconomic status having health outcomes similar to those of men of low socioeconomic status (Sen et al., 2010).
2. **Defining factors or variables.** Researchers need to define factors explicitly in order to be able to account for potential users (see Case Study: Public Transportation), explain health disparities, reduce publication bias, and conduct reliable meta-analyses (Schulz et al., 2006; Rommes et al., 2000).
3. **Identifying intersections between factors or variables.** Understanding how factors interrelate with sex or gender is important in explaining or predicting differences in health outcomes and determining user needs (Weber et al., 2007; Faulkner, 2004). For example, sex, socioeconomics, gendered divisions of labor, and language have all been found to interact in determining how agricultural workers are exposed to endocrine disruptors (see Case Study: Environmental Chemicals), and sex, geography, and gender relations interact to determine the technological needs of women and men (see Case Study: HIV Microbicides).

Related Case Studies

De-Gendering the Knee

Environmental Chemicals

HIV Microbicides

Human Thorax Model

Information for Air Travelers

Nanotechnology-Based Screening for HPV

Nutrigenomics

Osteoporosis Research in Men

Public Transportation

Engineering Innovation Processes

This method provides a framework for incorporating knowledge about sex and gender into engineering innovation. Engineering innovation here refers to any product, process, service, or infrastructure in the public or private sector.

This method assumes a basic understanding of other methods in this project: Analyzing Sex, Analyzing Gender, and Analyzing Factors Intersecting with Sex and Gender, and of the distinct meanings of sex and gender (see also Checklists: Engineering).

Integrating sex and gender into engineering innovation may:

- Lead to new products, processes, infrastructure, or services.
- Lead to design that promotes human well-being, including gender equality.
- Identify new markets and business opportunities.
- Develop technologies that meet the needs of a complex and diverse user group.
- Enhance global competitiveness and sustainability.

Each engineering organization has its own systems and processes for planning and managing innovation. This method offers elements that can be modified for the needs of specific systems.

1. Evaluating Past Innovation Practices

One route to developing Gendered Innovations is to recognize how choices made in the development of past innovations and technologies may have served certain groups of women or men more than others.

- Where have previous engineering innovation processes been blind or biased with respect to sex and gender?
    i. I-Methodology—whereby designers create products for users whose interests, abilities, and needs resemble their own—may result in a “male default” because men tend to be the majority of engineers in many economic sectors, such as automotive design and IT (see Case Study: Machine Translation).

Problems to Avoid when Analyzing Sex and Gender

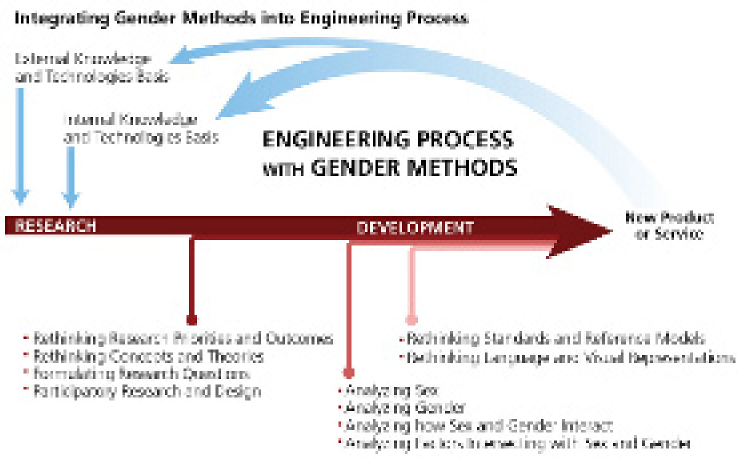
- *Being blind to potential differences of sex and gender* may result in missed business opportunities, with certain groups of people being left out, poorly accommodated, etc.
- *Treating "women" and "men" as homogeneous groups* ignores differences among women and among men.
- *Over-emphasizing differences between women and men* can cause engineers to overlook significant commonalities between women and men.
- *Designing to stereotypes* may result in unpopular products.

ii. Designing for "everybody" may also result in an unconscious "male default" (Oudshoorn et al., 2004). Although not labeled as such, the majority of video games, for example, are designed for boys and men (see Case Study: Video Games). Early speech synthesis by default produced men's voices, which limited its usefulness as an assistive technology (see Case Study: Making Machines Talk).

- When differences between women and men were considered, are they based on stereotypes? *Stereotyping* fails to capture actual people's attitudes and behaviours. Products or systems based on stereotypes may press people to conform to limiting or unequal roles. Potential customers and users may resent being constrained in this way and look elsewhere or modify products in an unauthorized manner. Products or systems based on stereotypes may reinforce or contribute to gender and other inequalities and not contribute to enhancing social justice or corporate social responsibility (Rommes, 2006).
- When products or systems are designed specifically for girls or women, are they built on stereotypes? Simply "pinking" plays to stereotypes and may miss important aspects of diversity in women's markets. For example, when Philips designers asked young girls what they thought about a toy called Kidcom that they were developing, the children rejected the round shapes and pink coloring that the designers had stereotypically chosen (Sørensen et al., 2011).
- What public works or business opportunities have been missed as a result of failing to understand sex or gender factors influencing a project? (See Case Study: Public Transportation.)

2. Building the Design Team

- Including **women**—their experiences, knowledge, and networks—on the design team can broaden perspectives (Danilda et al., 2011). Including women along with other populations is important for reasons of social justice, but does not ensure gendered innovation (Faulkner et al., 2007). One woman on a team, for example, does not represent all women.
- Including **gender expertise** can maximize innovation. Gender expertise can be recruited and developed in-house or from outside the project. Eventually, everyone on the team—women and men—will want to learn methods of sex and gender analysis relevant to their area. This is the most efficient way to rethink research priorities and to formulate research questions that lead to innovation (see Methods: Rethinking Research Priorities and Outcomes and Formulating Research Questions).



3. Analyzing Users and Markets

- In making choices about projects, engineers will analyze who does and who does not benefit from a particular project. It is important to analyze the differential effects of a system or product on women and men of different social, socioeconomic, and cultural backgrounds (Schraudner, 2010; see Method: Rethinking Research Priorities and Outcomes, and Case Study: HIV Microbicides).
- Relevant sex variables are biophysical (see Term: Sex; Methods: Analyzing Sex and Rethinking Standards and Reference Models; and Case Study: Pregnant Crash Test Dummies).
- Relevant gender variables are cultural, and they are related to specific gender norms, gender relations, and gender identities (see Term: Gender; Method: Analyzing Gender). Gendered behaviours in potential applications may shape patterns of use or access, etc. When considering gender, engineers should ground gender analysis in empirical evidence about *actual* people and *actual* practices, wishes, needs, and so on. Basing design on gender stereotypes may lead to unsuccessful products or systems.
- It is important to analyze differences between men and women, but one should also recognize and understand similarities (see Case Study: De-Gendering the Knee).
- It is important to analyze sex and gender, but it is also necessary to examine other factors intersecting with sex and gender. These factors or variables can be biological, socio-cultural, or psychological (see Method: Analyzing Factors Intersecting with Sex and Gender). Factors include age, reproductive status, educational level, socioeconomic background, and sexual orientation.

4. Obtaining User Input

Users and customers are a potential source of sex and gender intelligence for design and development. There are many ways to tap into users' potential gender knowledge.

- **Participatory research** typically seeks to balance interests, benefits, and responsibilities between users and design or engineering teams (see Method: Participatory Research and Design).

Participatory research is a way to access users' tacit knowledge—knowledge that may divide along gendered lines because of gender relations (see Case Study: Water Infrastructure).

- **Surveys, interviews, or focus groups.** These techniques must be used with care. Users may report behaving in gender-acceptable ways even if their actual behaviours differ; reliance on inaccurate self-reports can lead to unpopular products.
- **Objective measures.** To be reliable, measurements should not be based on self-reports. For example, on average, computer game players (women and men alike) underreport their gaming hours. Research that records actual player time allows more objective assessments of play (Williams, 2009).

5. Evaluation and Planning

Good practice requires an analysis of outcomes (see Method: Analyzing Research Priorities and Outcomes). Organizations will want to

- Consider both benefits and problems of the current product, process, service, or infrastructure. What successes can be built upon and what difficulties overcome?
- Consider how to develop gender expertise further. How can what was learned be further used across an organization and its innovation partners? What additional gender expertise is needed for future projects?

Related Case Studies

De-Gendering the Knee

Exploring Markets for Assistive Technologies for the Elderly

HIV Microbicides

Machine Translation

Making Machines Talk

Pregnant Crash Test Dummies

Public Transportation

Video Games

Water Infrastructure

Designing Health & Biomedical Research

All elements of biomedical research—the basic, applied, or translational research conducted to advance and support the body of knowledge in the field of health research and medicine—should take sex and gender into consideration. This recommendation applies over the wide range of study designs (survey, experimental, clinical trial, field trial, prospective, case/control, and more) and across multiple design aspects (see Checklists: Health & Medicine).

Health research addresses a broad range of factors that affect health of an individual or population, such as protective and risk factors, social determinants of health, environment, and resource distribution (see Method: Analyzing Gender). **Clinical research**, which evaluates the safety and efficacy of medications, devices, diagnostic procedures, and treatment regimens for preventing, treating, diagnosing, or relieving symptoms of a disease, generally of individuals, requires serious consideration of the study population (selection and eligibility criteria—i.e., sampling)—see Method: Analyzing Sex.

Sampling (Selection or Eligibility Criteria and Recruitment Strategies)

Enrolling a representative sample of the population for whom the study results may be generalized includes: a) determining characteristics which are likely to affect outcomes before initiating the study; and b) employing recruitment strategies that ensure enrollment of sufficient numbers of subjects whether animal or human. The goal is to have adequate statistical power to detect differences in outcomes. Variables with potential clinical significance include:

1. **Sex:** The epidemiology of many diseases and the safety and efficacy of many diagnostics and treatments differ by sex (see Method: Analyzing Sex). It should not be assumed, even for most standard, approved interventions, that similar effects will be observed in women and men. Substantial harm has resulted when data from single-sex studies (typically male only) has been generalized to both sexes (Kim et al., 2010). Female sex is a risk factor for certain adverse drug reactions, such as torsades de pointes, a life-threatening cardiac arrhythmia (Gupta et al., 2007). Since 1994, US legislation has required that women and ethnic/racial minorities be included in Phase III and subsequent clinical trials (1993 Revitalization Act). Nevertheless,
    a. **Even in clinical trials governed by the NIH Revitalization Act, women remain under-enrolled relative to their representation in the patient population** (see chart on Gendered Innovations website).
    b. **The Revitalization Act does not apply to early-phase medical studies.** Specifically, the NIH states that "an NIH-defined 'clinical trial' is a broadly based prospective Phase III clinical investigation, usually involving several hundred or more human subjects, for the purpose of evaluating an experimental intervention in comparison with a standard or control intervention or comparing two or more existing treatments" (NIH, 2001). Under this definition, Phase I and II studies are not clinical trials and therefore not subject to the provisions of the Act. When women are not included in Phase I and II, important discoveries related to sex may be missed. For example, a drug that works only in women may not be developed.

Common Pitfalls in Sampling

1. Conducting clinical trials or animal studies in only (or predominantly) one sex but generalizing results to both sexes.

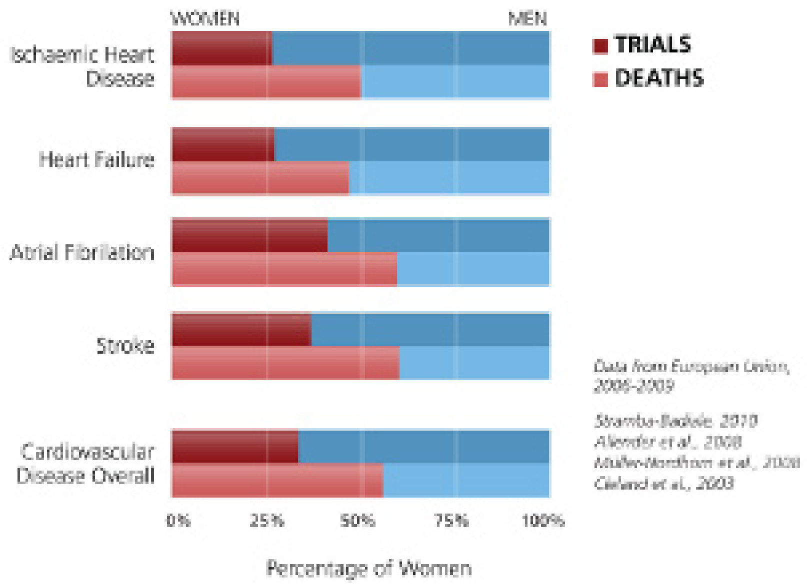
1. Assuming observed differences between females and males are due to sex (biology) without considering factors intersecting with sex (age, hormonal status, etc.).

3. Relying on meta-analysis to detect sex differences without adequately controlling for differences in participant characteristics, treatment parameters, data collection protocols, and outcome assessments. This is especially problematic when comparing all-female to all-male studies.

c. **Exclusion of women from clinical trials is not justifiable on the grounds of preventing birth defects or other harm to fetuses.** In the 1950s, prescription of thalidomide to pregnant women caused widespread birth defects and stillbirths, which in turn "spurred protectionist research policies which, ironically, often harmed women" (Gorenberg et al., 1991). Current policies strictly regulate pregnant women's enrollment in clinical trials; enrollment requires that "the risk to the fetus is caused solely by interventions or procedures that hold out the prospect of direct benefit for the woman or the fetus; or, if there is no such prospect of benefit, the risk to the fetus is not greater than minimal and the purpose of the research is the development of important biomedical knowledge which cannot be obtained by any other means" (Department of Health and Human Services, 2001). Similarly strict guidelines apply to enrollment of children in medical research (Code of Federal Regulations, 2009; European Parliament, 2001).

In some cases, researchers have applied the strict enrollment regulations (designed to protect pregnant women) to all women of childbearing potential (i.e., all women between menarche and menopause), effectively excluding these women from basic research (Kinney et al., 1981). Such "protectionist" policies can in fact endanger pregnant women, as "new drugs and devices are typically not approved for use" in pregnancy (Baylis, 2010). Even though many clinical trials enroll patient cohorts of an age where most or all women are post-menopausal, women remain underrepresented.

Percentage of Women in CVD Clinical Trials vs. Deaths
Women are underrepresented in CVD clinical trials



In recognition of this deficiency, the European Medicines Agency (EMEA) has asserted that matching the demographics of a study population to the demographics of patients eligible to receive a given treatment is "an underlying principle of drug development." (EMEA, 2005). In the specific context of cardiovascular diseases, EMEA has emphasized the need for research on possible sex differences in "lipid profile, hormonal status and influence of menopause, body composition, etc.," which may be relevant to understanding why sex differences are observed in prognosis and in the efficacy of diagnostic tests (EMEA, 2006).

2. **Reproductive (or Hormonal) State:** Both females and males have profound hormonal changes: at puberty, with aging, and for females, across the estrus or menstrual cycle, during and after pregnancy, and during the menopausal transition. These hormonal changes have widespread physiological effects, producing changes in immune function, fluid balance, temperature control, and body composition. Researchers should consider these effects in planning research, and where appropriate (Becker et al., 2005):
   a. Sample naturally ovulating women at different phases of the menstrual cycle (or female animals at different phases of the estrus cycle—See Case Study: Animal Research).
   b. Take into account the widespread use (and effects) of exogenous hormones, such as oral contraceptives, menopausal hormones, and androgens.
   c. Sample women at various points of a pregnancy and post-partum.
   d. Collect data on early and late peri- and post-menopausal status in studies of middle-aged women.
3. **Gendered Behaviours:** Gender roles and identities influence disease risk factors as well as treatment and outcomes, so they may need to be considered in biomedical studies. Gendered factors of biomedical significance may include:
   a. Gendered divisions of labor that expose women and men to different risks. For example, in developed countries, men perform most pesticide application and women perform most household cleaning, and therefore women and men may have contact with different groups of endocrine-disrupting chemicals (see Case Study: Environmental Chemicals).
   b. Cultural gender norms that create differences in women's and men's health behaviours. Gender differences exist in protective behaviours—for example, older men exercise more than age-matched women, and exercise promotes bone health (see Case Study: Osteoporosis Research in Men). Gender differences also exist in risk behaviours—for example, in Western countries, men are more likely to smoke tobacco (a risk factor for cardiovascular diseases and many cancers), whereas women are more likely to use ultraviolet tanning beds (a risk factor for skin cancer).
4. **Factors Intersecting with Sex and Gender:** Variables such as age, body composition, and comorbidities often correlate (co-vary) with sex and may confound results if not taken into account. For example, because cardiovascular (CV) events are diagnosed at younger ages in men than in women, and many CV trials have age cut-offs, a smaller proportion of women have been eligible for most CV trials. Further, women who are enrolled in CV trials, such as those of cholesterol-lowering statin drugs, have tended to be older and have more (age-related) comorbidities than men (Dey et al., 2009). Comparing the results of male-only and female-only CV trials without accounting for age can lead to misinterpretation of trial findings.

   Although it is important that researchers sample sufficient numbers of people of both sexes, single-sex studies may be preferable to mixed-sex studies under the following circumstances:
   a. **Studying conditions affecting only women or men.** These are generally disorders of reproductive organs, including sex-specific cancers such as ovarian cancer in women and prostate cancer in men. Other single-sex disorders include menstrual and menopausal conditions, pregnancy and childbirth, and erectile dysfunction.

b. **Medical diagnostics and interventions already tested extensively in one sex.** For example, it was reasonable to study the safety and effectiveness of the HPV vaccine in young men only (Giuliano et al., 2011), after it had been extensively studied in young women (Future II Study Group, 2007). Similarly, many osteoporosis drugs have been studied extensively in women, but have not yet been studied in men.
c. **Differences (or similarities—i.e., prior studies support no significant differences) in disease development, diagnosis, or treatment are already well understood.** In this case, single-sex studies can allow researchers to examine differences within each sex, often through analysis of factors intersecting with sex. For example, the Women's Ischemic Stroke and Evaluation (WISE) study evaluated angina that was present with no obvious obstructive coronary disease in women only, noting that it is much less common in men, and determined several underlying causes of ischemia (Shaw et al., 2008).

Study design should build in strategies to ensure that women and men enrolled in a study receive similar interventions and are retained at similar high levels, and that comparable data are gathered.

In some cases, retrospective analysis may be performed. For instance, researchers might compare treatment effects in a set of female-only studies of a particular drug and male-only studies of the same drug. Though neither group of studies is able to detect sex differences, a meta-analysis of the two studies might demonstrate such differences. Retrospective analysis is, however, much less reliable than prospective analysis—see Common Pitfalls in Sampling.

Related Case Studies

Animal Research

Brain Research

De-Gendering the Knee

Environmental Chemicals

Heart Disease in Women

Nanotechnology-Based Screening for HPV

Nutrigenomics

Osteoporosis Research in Men

Stem Cells

Participatory Research and Design

Much knowledge is divided between women and men because labor (both formal employment and uncompensated domestic and caring work) divides along gendered lines. These divisions of labor also lead to differences in the tools and resources women and men use. For example, most commercial drivers are men, and these men may have valuable insights for developing technologies related to ground transport. Analyzing sex- and gender-specific experience can serve as a resource for knowledge production and technology design.

Participatory research methods are used in a wide range of fields, from industrial product design to epidemiology to software engineering. Although specific methods are diverse, participatory research involves users or research subjects in tasks such as setting research objectives, gathering and processing data, and interpreting results (Gonsalves et al., 2005; Leung et al., 2004; O'Fallon et al., 2002; Greenwood et al., 1993). Participatory research typically seeks to balance interests, benefits, and responsibilities between the users/subjects and the research institutions involved. Further, participatory research seeks to make the entire process, from planning to reporting, transparent and accessible to all parties (WHO, 2011).

Practical Steps for Incorporating Sex and Gender Analysis into Participatory Research—Researchers should:

1. **Identify the area of work or everyday life they wish to address:** Investigate gendered structures in that area and make sure to consider subareas that may have been overlooked. Note that:
    a. Women may have specific product needs, such as menstrual hygiene products or sports brassieres (Vostral, 2008; Faulkner, 2001; Maines, 1999; McGaw, 2003; Cowan, 1983); men too may have specific product needs, such as male birth control (Oudshoorn, 2003).
    b. Women or men may have specific knowledge to contribute (see Case Study: Water Infrastructure).
2. **Identify potential target groups:** Conduct surveys or literature reviews, assemble focus groups, send out questionnaires, and so on. What are the characteristics of target users/communities (these may include sex, age, socioeconomic status, ethnicity, native language, etc.)? Questions include: How will different groups of people (defined by sex, race, age, geographic location, etc.) be affected by this project/product? What are their particular perspectives and interests? Whose practical knowledge or experience is relevant to this research or design project? For example, seatbelt designers could partner with pregnant women to design a seatbelt that works better for them (see Case Study: Pregnant Crash Test Dummies).
3. **Seek user or community input:** Engage users/communities in defining problems, requirements, and solution and design alternatives (Oudshoorn et al., 2003: Oudshoorn et al., 2002). Interviewing users—both men and women—allows researchers or engineers to gather information about how a technology, a product, or a public health measure will affect their everyday lives, assist their work, or enhance their leisure. How do gender roles influence the data collected or the outcomes of a project? For example, because of historical gender divisions of labor and women's role as primary healthcare givers, women are often the holders of traditional knowledge about medicinal plants (Voeks, 2007). Conversely, men are often responsible for gathering plants for use as building materials and are likely to be the primary holders of traditional knowledge about them (Camou-Guerrero et al., 2008). Seeking input from the most knowledgeable user may be important in conservation projects.
4. **Observe workers or users:** Observing people at work allows scientists and engineers to access "tacit" knowledge—knowledge that is self-evident or "taken for granted" by workers themselves and rarely articulated. Capturing tacit knowledge may bring new perspectives to formal research and design. Researchers might ask: How do sex and gender influence how the work is done, how an artifact is used, or how a process works? How may this differ in a single-sex versus mixed-sex context? Engineers and designers can probe their understanding in interaction with users. For example, to develop new software for

customer-service call centers, ICT researchers observed, interviewed, and worked with call center employees—a majority of them women—to understand their needs. Analyzing the gendered nature of the work and gathering user input produced software that better captured previously unrecognized needs (Maass et al., 2007).

5. **Evaluate and redesign:** Researchers can cooperate with users/communities in all steps of project evaluation, from defining goals or measures of success to determining whether these goals have been achieved in the design, implementation, and monitoring steps (WHO, 2002). User and community input can also help to guide product redesign and further research.

Related Case Studies

Exploring Markets for Assistive Technology for the Elderly

Housing and Neighborhood Design

Information for Air Travelers

Video Games

Water Infrastructure

Rethinking Standards and Reference Models

Standards and reference models are integral to science, health & medicine, and engineering; they are used in educating students, in generating and testing hypotheses, in designing products, and in drafting legislation. Standards and reference models based on a single sex (or particular groups of men or women) can have damaging material consequences (see Case Study: Pregnant Crash Test Dummies). Standards and models are based on available data and are therefore sensitive to sampling decisions made in Designing Health & Biomedical Research and in Engineering Innovation Processes.

Science, medicine, and engineering often take the young, white, able-bodied 70kg male as the norm (see Figures 1 and 2). When studied at all, other segments of the population—women, the elderly, and non-white groups—are frequently considered as deviations from that norm. Occasionally women's bodies set the norm, as in the example of osteoporosis diagnostic criteria (see Case Study: Osteoporosis Research in Men).

Standards and reference models are shaped by and shape gender norms:

1. **Standards often default to male.** For example, in the 1970s the majority of automobile crash test dummies modeled only the 50th percentile US man. By the 1980s and 1990s, a wider range of dummies—representing diverse heights and weights—were used in vehicle safety tests. By expanding the modeling base, engineers took the safety of women, men, and multi-ethnic populations into consideration (see Case Study: Pregnant Crash Test Dummies).
2. **Gender norms influence the choice of reference species.** For example, primatologist Linda Fedigan has discussed the 1950s myth of the "killer ape," the pervasive image of primates engaged in bullying aggression toward females and violent infighting among males. This image of aggressive primates was drawn almost exclusively from studies of savannah baboons—taken as a "reference species"—in a process that Fedigan has called the "baboonization" of primate life (Fedigan, 1986).

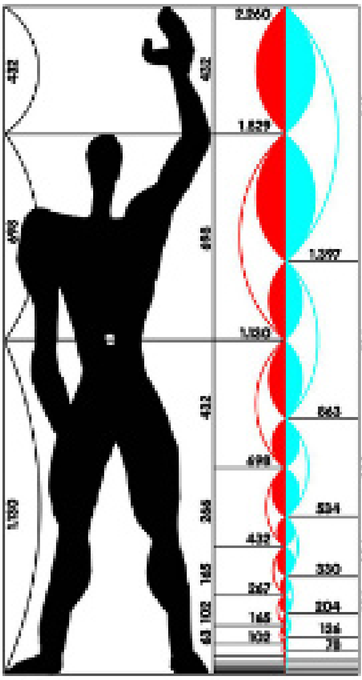


Figure 1. Le Corbusier created the "Modulator" in the 1940s to set standards for the human body in architecture and mechanical design. The Modulator—and similar models ranging back to da Vinci's Vitruvian man—sought to define the "range of harmonious measurements to suit the human scale" (Le Corbusier, 1954). "Human" here is persented as a 1.75 meter man (Hosey, 2001).

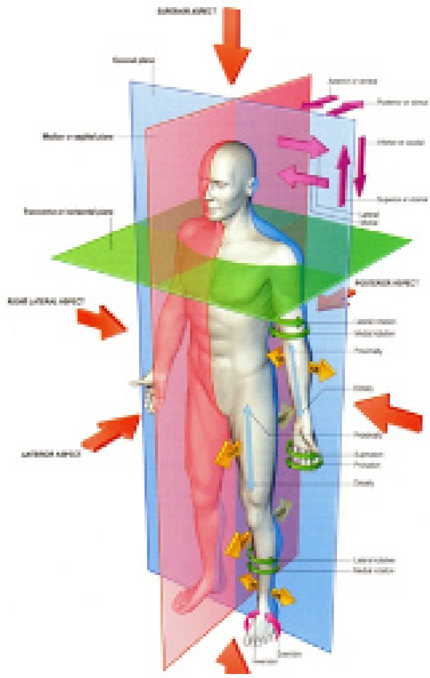


Figure 2. The 70kg male body is often used as a standard reference model in anatonimal textbooks.The 2004 edition of Gray's Anatomy details anatomical features using the male body. Female bodies appear to show where they deviate from males, especially in primary and secondary sexual characteristics (Standring, 2004).

3. **Reference subjects influence gender norms.** For example, in rodent research, "reference females" are usually non-pregnant and non-lactating. Behaviourally, these females are less aggressive than males—a finding congruent with assumptions about gender. Changing the female mouse model to a pregnant or lactating animal would alter the outcome of a behavioural study: Female mice are aggressive in controlling food sources when pregnant or caring for pups (Brown et al., 2010).

Significant Gendered Innovations result when researchers and engineers critically analyze standards and reference models for sex and gender bias, and revise as necessary by asking:

- How are standards established? What input do stakeholders have, and who is identified as a stakeholder? What are the goals of specific standards, and how is progress toward these objectives assessed? Will the outcomes of research be applied or offered to groups not represented by the standard, such as individuals of a different sex?

- How are models chosen? What reference models are preferred in a given discipline, and how and why were they selected? Would adopting a different reference model produce a different outcome or lead to different conclusions about sex and gender?

Checklist

✓ When analyzing human standards and reference models, researchers/engineers will want to consider the following questions:

a. Does the existing model differentiate between women and men?

b. Are existing standards up-to-date, or based on old data that might be invalidated by trends? For example, the incidence of obesity has increased significantly in highly developed countries over time (WHO, 2011). Japan, Brazil, the U.K., and the US have all seen rates of obesity roughly triple in less than 30 years (Jeffrey et al., 2008).

c. If a model does *not* consider sex, is it based on research in both sexes, or is it in fact a male reference model (or, in some cases, a female reference model) that is being improperly used as a generic "human" model?

d. If standards *do* consider sex, how important is sex to the reference model? Have researchers adequately investigated non-biological influences due to gender and other social or biological factors?

e. Beyond considering sex differences, does the model address sex-specific factors among women (such as pregnancy) and men (such as susceptibility to prostate cancer)?

f. Does the existing model take into account differences between women's and men's attitudes, needs, and interests?

✓ When analyzing experimental reference models, researchers will want to consider the following questions:

a. Are reference models by default based on one sex but taken to be valid for the species overall?

b. Do data for one sex lag behind data for another sex, so that sex-specific reference models may not be equally developed or validated?

c. What criteria are used in selecting species, strain, and sex of model organisms used in research that will be translated to humans?

d. Does the choice of a particular model organism significantly affect findings?

Related Case Studies

Animal Research

Human Thorax Model

Osteoporosis Research in Men

Pregnant Crash Test Dummies

Rethinking Language and Visual Representations

Language and visual representations are central to all knowledge-based activities, including those in science, health & medicine, and engineering. Word choice, charts, graphs, images, and icons have the power to shape scientific practice, the questions asked, the results obtained, and the interpretations made. "Sharing a language means sharing a conceptual universe" within which assumptions, judgments, and interpretations of data can be said to "make sense" (Keller, 1992). Rethinking language also involves Rethinking Concepts and Theories.

Rethinking language and visual representations can:

1. Remove assumptions that may limit or restrict innovation and knowledge in unconscious ways.
2. Remove assumptions that unconsciously reinforce gender inequalities.

Language

Consider the following examples:

1. **Unintended hypothesis-creating metaphors.** Analogies and metaphors function to construct as well as describe. They have both a hypothesis-creating and proof-making function. By analyzing language—by "waking up" metaphors—we can critically judge how the imagery may be lending structure to our research (Martin, 1992). For example, zoologists often refer to herds of animals (horses, antelope, elephant seals, etc.) as "harems." The word "harem" embeds assumptions about social organization, in this case polygyny. In this example, researchers failed to "see" what lies outside the logic of the metaphor. Recent DNA studies of mustangs show, however, that a given stallion typically sires less than a third of the foals in a band. Researchers who questioned the notion of a "harem" found that female mustangs range from band to band, often mating with a stallion of their choice (Brown, 1995).
2. **Inclusive language.** Inclusive language may enhance recruitment and retention of women in traditionally masculine fields, such as engineering—and may similarly enhance recruitment of men in traditionally feminine fields, such as nursing or psychology.
   - In English, "she and he" should be used rather than the generic "he" when referring to a researcher, subject, or student whose sex is unknown. Often, recasting a sentence in the plural solves the problem of referents.
   - In English, new words have been devised and usage altered to be more inclusive. For example, "fireman" has been replaced with "fire fighter," and "animal husbandry" can be replaced with the more neutral "animal breeding." "Infantrymen" are now commonly called "soldiers." Some old terms, such as "aviatrix" and "lady doctor," have completely disappeared.

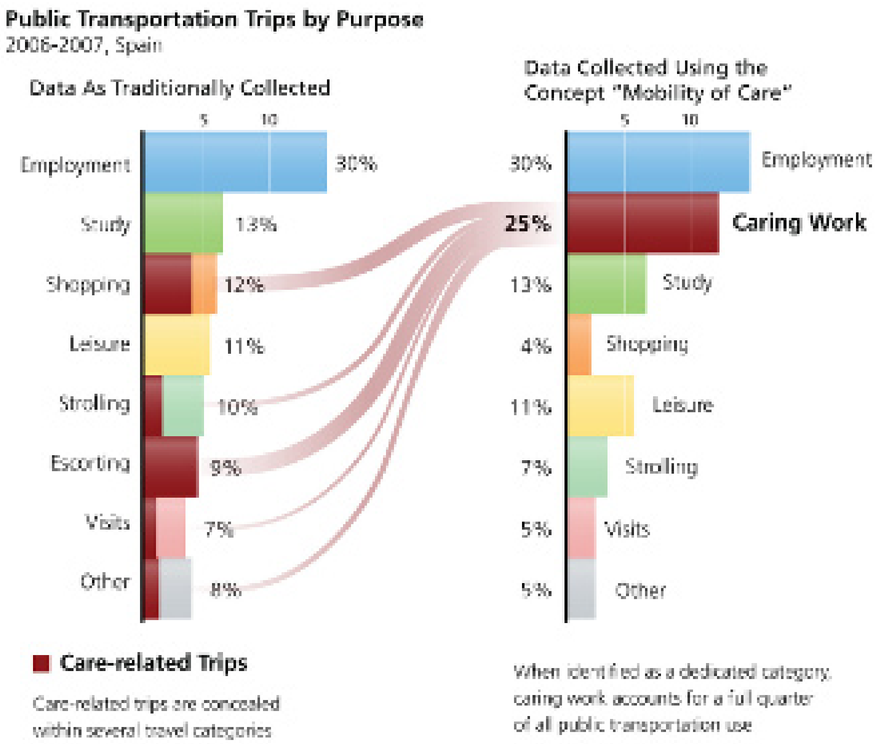
Visual Representations

Visual representations in science, medicine, and engineering may contain gender-inflected messages in: 1) the content of a field or discipline, or 2) the practitioners of a field or discipline. Consider the following:

Visual Display of Data

Visual displays of data may embed gender assumptions. As discussed in the case study on Public Transportation, the charts below represent trips made in Madrid in 2007. The first chart (left) graphs transportation data as traditionally collected and reported. It privileges paid employment by presenting it as a single, large category. Caring work (shown in red) is divided into numerous small categories and hidden under other headings, such as escorting, shopping, and leisure.

The second chart (right) reconceptualizes public transportation trips by collecting care trips into one category. Visualizing care trips in one dedicated category emphasizes the importance of caring work and allows transportation engineers to design systems that work well for all segments of the population, improve urban efficiency, and guard against global warming (Sánchez de Madariaga, 2011).



Checklist

✓ When rethinking language and visual representations, consider the following:

- How might metaphors be gendered and create unintended hypotheses?
- Do gendered metaphors reinforce stereotypes?
- Are word choices or naming practices gendered?

- How does nomenclature influence who becomes a scientist or engineer?
- Are the language and images being used gender inclusive?
- Are graphs, charts, or images used to visualize abstract concepts gendered in unintended ways?
- Does a particular field of science or engineering promote a self-image that carries messages about the "gender appropriateness" of participation by women and men?
- Are problem sets or training exercises chosen to illustrate basic scientific principles gendered in unintended ways?

Related Case Studies

Public Transportation

Textbooks

Video Games

ANNEX D: Contributors

Funding Organisations

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Opinion polls suggest that women are less interested in innovation than men. The explanation surely lies elsewhere: do today´s innovations really respond adequately to women´s needs and expectations? In too many cases they do not.
Thirty years of research have revealed that sex and gender bias is socially harmful and expensive. Gender bias also leads to missed market opportunities.
Gendered Innovations offer sophisticated methods of sex and gender analysis to scientists and engineers. This publication includes case studies as concrete illustrations of how sex and gender analysis lead to new ideas and excellence in research in several fields such as health & medicine, environment & climate change, food & nutrition, transport and technological development."

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