

EPIDEMIOLOGY:

1. INTRODUCTION

The health professions that most people interact with are clinically oriented.

These professions – medicine, dentistry, nursing, pharmacy, physical therapy, occupational therapy, for example – are primarily focused on individuals. In contrast, epidemiology and other public health professions have as their primary concern the health of populations. This population perspective distinguishes public health from clinical professions. This lecture will describe and illustrate the population perspective.

Demography is a science that studies populations, though without a specific focus on population health. Epidemiologists make extensive use of demographic concepts, techniques, and information. All of us see the world through our perspectives. My perspective as a faculty member is different from your perspective as a student. Each of us employs numerous perspectives, according to our role and responsibilities in a given activity and our objectives. In public health we differentiate between two types of perspective

- the individual perspective
- the population perspective.

Epidemiology emphasizes the population perspective.

The **individual perspective** focuses on the health, risk factors, exposures, and causal mechanisms in people as individuals. Coronary heart disease, cancer, stroke, injury, hypertension, infections, birth defects, asthma, dementia – these are all conditions and events that occur to or in individuals. Everyone has a genetic make-up, early life experience, diet, substance use, physical activity, use of medical care and other characteristics that affect her or his risk for various health outcomes. Preventing and treating health conditions at the individual level is the focus of clinical professions – and of the public health professions. For example, many epidemiologic studies seek to identify risk factors and causal mechanisms linking those factors to individual health outcomes.

By contrast, the **population perspective** focuses on disorders that occur in large numbers of people, sometimes referred to as “mass disease”, and how these disorders are influenced by the physical and social environment. The exposures and causal mechanisms involved are those that function at the level of the group.

2. POPULATION PERSPECTIVE VS. THE INDIVIDUAL PERSPECTIVE

Let's contrast the individual and population perspectives on the lung cancer epidemic and its control. The individual perspective is concerned with identifying the factors at the individual level that cause lung cancer. Following the demonstration that smoking is a very strong risk factor for lung cancer, the individual perspective examines the factors that lead people to start smoking and help them to quit, and with provision of services to help individuals quit

smoking. Smoking cessation clinics, for example, assist people who want to quit to become free of their addiction.

In contrast, the population perspective is concerned with the environmental factors – social, economic, technological, political, etc. – that promote smoking in the population.

Mass disease – the primary concern of public health – of necessity arises from population-level influences. So the population perspective is fundamental to public health and epidemiology.

3. POPULATIONS ARE DYNAMIC, DIVERSE, HETEROGENEOUS - DEMOGRAPHIC FACTORS

Populations are dynamic

- changing over time, diverse
- different from one another, and heterogeneous
- composed of disparate subpopulations.

Among the key health-related characteristics of populations are their:

• size and density • age distribution • sex ratio • geographical distribution • ethnic composition • level and distribution of education • level and distribution of economic resources
Key health-related demographic events and processes include: • birth • marriage • migration • aging • death

We cannot continue to grow multiply, yet moving toward zero population growth presents many challenges. First, we'll look at data on mortality, life expectancy, health status, and fertility.

MORTALITY

Mortality is a key indicator of population health, and **age** is a key determinant of mortality.

Any comparison of mortality rates across populations or groups within a population must in some way account for the age and gender distributions of the groups being compared.

Table 3

Life Expectancy at Birth and at Age 65 in Years, by Sex, 1900, 1950, and 2000

	At birth			At age 65		
	Total	Male	Female	Total	Male	Female
1900	47.3	46.3	48.3	11.9	11.5	12.2
1950	68.2	65.6	71.1	13.9	12.8	15.0
2000	76.9	74.1	79.5	17.9	16.3	19.2

Sources: National Center for Health Statistics, *Health, United States, 2000* (2001): table 28; and A.M. Minino and B.L. Smith, *National Vital Statistics Reports* 49, no. 12 (2001): table 6.

This table shows life expectancy at birth and at age 65, by sex, in three different years. Life expectancy is essentially a summarization of the mortality rates at each age, such as those presented in the preceding slide.

To estimate **life expectancy** in a given year, we take a hypothetical cohort of people and imagine that they pass through life from birth to death, being subjected to the mortality rates that we are summarizing. So, if we began with 100,000 babies, estimate how many would still be alive by their first birthday, then estimate how many of these would still be alive by their second birthday, and so on until the cohort had all died, we could add up the number of years lived by each person in the cohort and divide by 100,000.

The result is the life expectancy at birth.

So, the female life expectancy at birth in 1900 – 48.3 years, as given in the table – is obtained as the average number of years that each member of a cohort of females would have lived if they experienced the mortality rates recorded in 1900 for each age group. The life expectancy at age 65 is estimated by taking the number of years lived after age 65 and dividing by the number of people who reached age 65. Note that life expectancy is not a projection or prediction. For the life expectancy in 1900 we use the mortality rates for each age as they were in 1900. But mortality rates have been declining over time, and by the time that someone born in 1900 was age 50, she would experience the mortality rate in 1950 rather than that from 1900. So, life expectancy is a way of summarizing the mortality rates across all ages at a specific time, rather than a prediction.

The life expectancies shown in the table, which come from the National Centre for Health Statistics, show that life expectancy increased substantially during the 20th century, more so for females than for males. Life expectancy at birth was 46.3 and 48.3 years, respectively, for

males and females in 1900. By 2000 these figures had become 74.1 and 79.5 years, an increase of about 30 years. The male-female gap in life expectancy, which was two years in 1900, had grown to over 5 years by 2000.

Life expectancy is most heavily influenced by mortality rates at young ages.

Improvements in nutrition, hygiene, and conditions of living (housing, child labor), immunizations, and reductions in maternal mortality reduced mortality among infants, children, and women in their reproductive years. These reductions were responsible for much of the increase in life expectancy during the first half of the 20th century. Reductions in childhood mortality, of course, have no effect on life expectancy at age 65. Even the elimination of a cause of death such as heart disease can increase life expectancy only modestly, since mortality rates from other causes are so high. Nevertheless during the 20th century life expectancy at age 65 increased by about 4 years for males and 7 years for females, a substantial gain.

We've been referring to birth rates, mortality rates, and so forth, without defining them. Let's make sure that we all understand these important demographic measures.

A birth rate is a ratio of the number of births during a period divided by a reference population. The most cited birth rates are **"crude" birth rates** for specific years, calculated as the total number of live births in the year divided by an estimate of the total population at mid-year.

The reason for using the mid-year population is that if the population is steadily increasing, as is commonly the case, the mid-year population provides a close approximation to the average number of people in the population on any given day. The use of the mid-year population as a kind of compromise between the starting and ending populations is a common practice for vital statistics rates.

Note that the denominator for the crude birth rate consists of both women and men, of all ages, even though most can neither bear children nor father them.

To reduce the number of decimal places, birth rates are customarily expressed per 1,000. Although commonly omitted, the time units of the rate (usually "per year"), should be stated, since even though the births were accumulated for one year, the number itself can be expressed "per month", "per week", "per decade", or with respect to any other time unit. Related to the birth rate is the general fertility rate, which expresses the number of births in a year relative to the number of women of reproductive age. Again, the estimated mid-year population is used, and the result is usually expressed per 1,000 women of reproductive age. Again, "per year" is generally intended but is stated only infrequently. The fertility rate requires more information about the population and gives a more specific indication of reproductive behaviour. You've probably already guessed that an annual death (or mortality) rate is estimated as the number of deaths divided by the mid-year population per year and is often expressed per 1,000 people. Again, "per year" is generally intended but is stated only infrequently. As with the crude birth rate, the denominator for the crude death rate includes

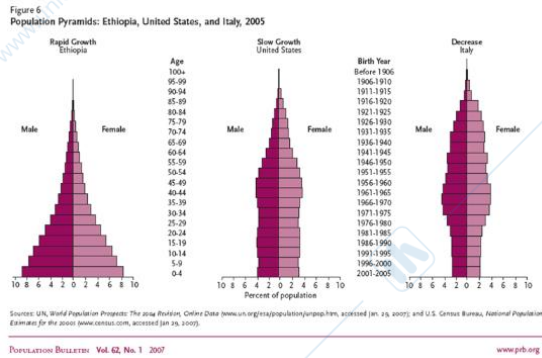
the total population (men, women, and all ages), even though mortality rates vary greatly by age and gender. For this reason, the overall death rate is not used very often. More typically death rates are calculated for specific subgroups defined by gender and age. When an overall figure is desired, the rates for the different age groups are combined as a weighted average – the resulting average is called an “age-adjusted” or “age-standardized” mortality rate and is typically computed separately for males and females. As we have seen in earlier slides, death rates may be estimated for specific causes of death, such as all cancers, specific cancer sites, heart disease, and so on. A major concern in interpreting all vital statistics and epidemiologic rates is the quality of the data that were available to calculate them. In developed countries, birth records, death records, and population size estimates are generally available and accurate. Information on cause of death, however, is much less reliable, since there are various definitional and practical obstacles in accurately classifying deaths as to cause. Thus, before relying on data on cause-specific mortality, it is important to assess the likely accuracy for each specific cause of death being analysed. More problematic is the situation in less-developed countries, where population counts, and vital events registration may be incomplete to varying degrees. When a rate is estimated from a small number of events, the resulting estimate is unstable. If even a few events were miscounted, or if there were a minor variation that particular year, the rate could be misleading. Estimates based on small numbers are called “imprecise” or “unreliable”, and generally avoided. A common strategy, therefore, is to estimate an average over several years, as a way of obtaining a larger number of events for the calculation.

The denominator actually includes the time interval during which the deaths have accumulated, and therefore should include the units in which that time interval is expressed (e.g., years). Although the units are typically omitted when vital statistics rates are presented, they are in fact ambiguous without their units, usually “per year”. Now we will touch on several aspects of population structure and transformation, including population age structure, growth, fertility, fertility momentum, the demographic transition, and population aging.

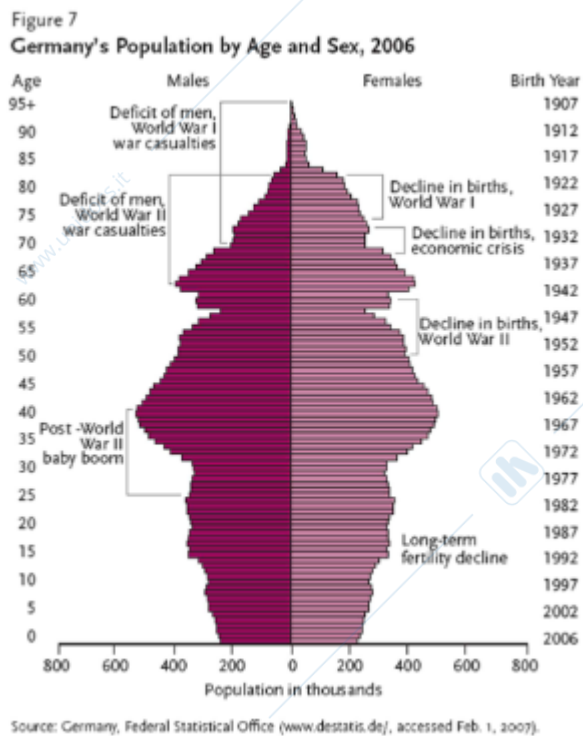
4. POPULATION STRUCTURE

The age-sex make-up of a population is often displayed in a “**population pyramid**”.

A population pyramid is constructed by drawing a series of horizontal bars stacked one on top of the other. The bars represent age strata and generally have the same height (e.g., representing 5-year age bands). The width of the bars is drawn to correspond to the proportion of all males (on the left) and all females (on the right) who fall into that age band. Since age and gender are such fundamental characteristics in many areas of life, including health, the age and gender structure of a population, as presented in its population pyramid, tells us a lot about the population growth Population growth.



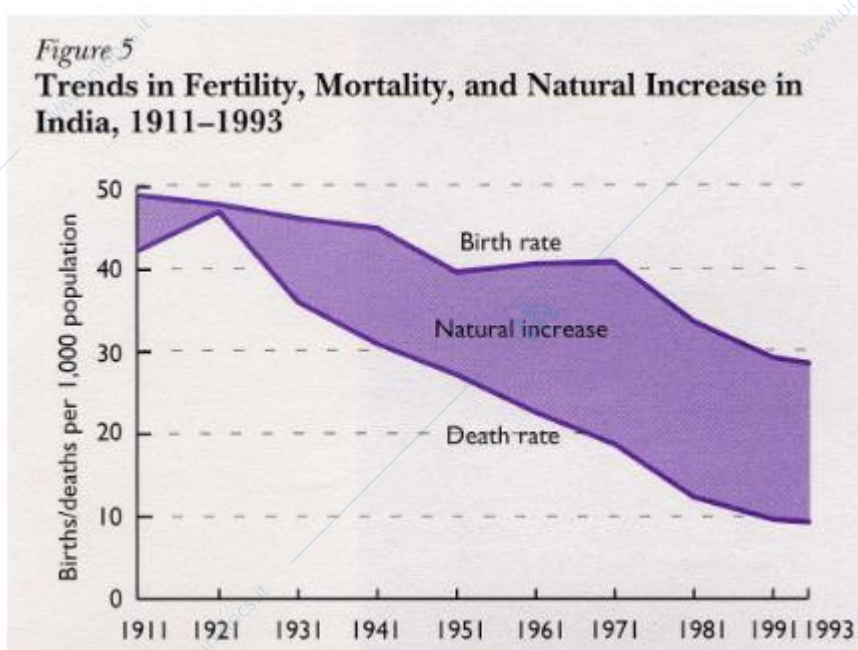
The graph in this Figure shows population pyramids for three different countries, illustrating three basic population structures. A population pyramid shows the record of a population's history. On the left, the pyramid for Kenya depicts a rapidly growing population. How can we see that from the pyramid? The narrow middle and top and widening base indicate that each new birth cohort is larger than the previous one. With the passage of time, each age band moves up the pyramid, so these larger cohorts are expanding the total population. High adult mortality rates help to narrow the pyramid at the top. The centre pyramid shows the U.S., a slow-growth population. The bands at the base are narrower than those in the middle, indicating a lower fertility rate. The bulge in the middle corresponds to birth years 1945-1965, approximately the “baby boom”. The pyramid for Denmark, on the right, depicts zero growth. This figure for Germany's population in 2006 we see the deficits of men from casualties in the two World Wars as well as declines in fertility during the wars, during the economic crisis, and in the modern era.



Comparing population pyramids over time shows how rising and falling birth rates and population aging influence the age-sex distribution over time. This slide shows the U.S.

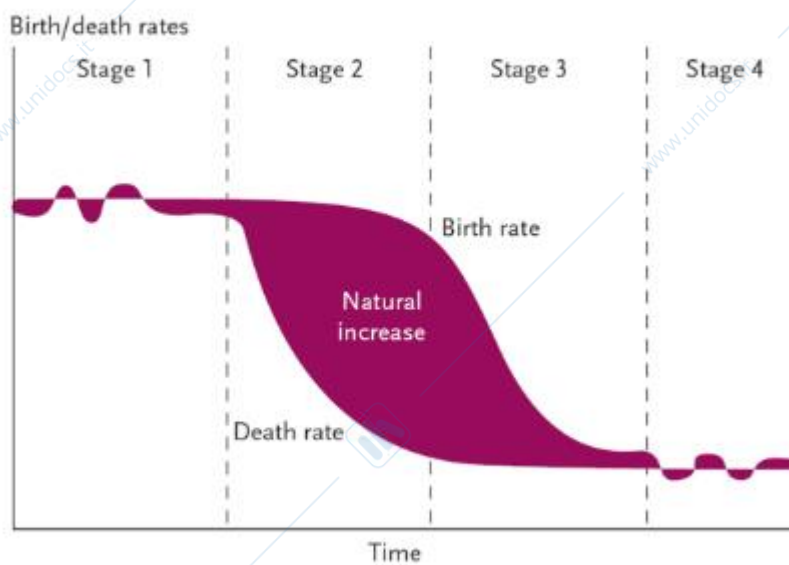
population by age and sex, in 1900, 1970, 2000 and projected for 2030. The graph for 1900 – in the upper left of the slide – actually looks like a pyramid, as did the one for Ethiopia. The slope of the sides of the U.S. pyramid is less steep, though, corresponding to a lower birthrate and perhaps higher infant mortality. The U.S. in 1900 was growing from immigration as well as births, which also makes for a broader pyramid. The pyramid in the upper right (1970) looks markedly different, almost as if the 1900 distribution had had a girdle placed around the 30–39-year age band, so that the younger population had not been allowed to grow up. The narrowing in the age groups from ages 25–39 reflects the decline in fertility during the Great Depression of the 1930s and World War II. Children born in 1944 were about 26 in 1970 (see my picture?), those born in 1939 were 31 in 1970, and those born in 1930 were 40. The younger age bands – ages 5 through 24 – show the Baby Boom. In this way, a population pyramid displays the reproductive history of a population. Reflecting on the shape of the 1970 pyramid, with its substantially greater ratio of youth to parents, it's no wonder that the 1960s and 70s were such a transforming time in the U.S. Coming closer to home, chronologically speaking, the lower left pyramid for the year 2000 shows the Boomers at maturity and the “Boomlet” of their offspring. In the spirit of “Where’s Waldo”, find my picture next to the caption “Men”. By 2030, I predict that funding for the NIA will have eclipsed that for NICHD. Moving to the other Figure of the globe, this graph shows population growth in India during the 200 years from 1801–2001. The second country to pass the one-billion population mark, India is home to about one-sixth of the world’s population. The population growth curve mirrors that for the world as a whole. Each year there are more women in their reproductive years and, even with the same fertility rate, there are more babies. If the curve were redrawn to show the percentage increase in population each year (e.g., by plotting the data on a logarithmic scale), the decline in the growth rate would be visible.

Fertility



This graph shows trends in fertility, mortality, and natural increase in India during the same period, revealing the dynamics of India's population growth. The birth rate has declined during most of the century. The death rate has declined more rapidly, however, an achievement of public health measures. The difference between the two is called the **rate of natural increase** and constitutes one component of the population growth rate (the other is immigration, which in the case of India is relatively minor). The rate of natural increase grew rapidly from 1921 to 1971, when the birth rate began to decline more steeply. This pattern illustrates what has been called the demographic transition, which we describe next.

Figure 11
The Classic Stages of Demographic Transitions



Note: Natural increase or decrease is produced from the difference between the number of births and deaths.

The demographic transition is a general pattern of changes in death rates, population growth, and birth rates that appears during the process of modernization.

Demographers distinguish four stages.

Stage 1 is the period before the transition begins. Birth rates are high, but so are death rates, so population size is stable.

The transition period begins when death rates fall, as improvements in agricultural productivity, economic development, and introduction of modern sanitation, immunization, improved nutrition, and other public health measures become available. However, cultural values, considerations of personal security, personal preferences, and the priorities of the health professions continue to support the high birth rate. The population begins to grow rapidly.

The transition from stage 2 to stage 3 begins when, under the influence of such factors as the effects of land shortages, urbanization, education of women, and introduction of family planning programs, the birth rate begins to decline.

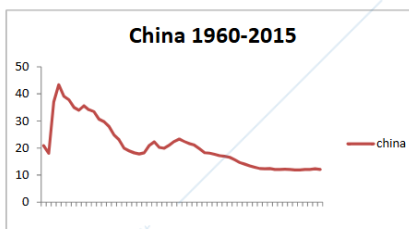
In **stage 3**, the decline in the birth rate exceeds that in the death rate, which comes to stabilize at a low level. Population growth continues, but at a declining rate.

In **stage 4**, the transition has been completed, as the birth rate joins the death rate at a stable, low rate, and population size stabilizes. The lower birth rate can produce a “demographic dividend” from fewer dependents per working-age adult, giving a country the opportunity to invest in health care, education, economic development, and infrastructure before the population ages.

Demographic Transition.

Let's pause here to explain the concept of the total fertility rate (TFR). The **TFR** is a summary measure, constructed in a manner reminiscent of life expectancy. For biological and social reasons, fertility (the number of babies divided by the number of women in their reproductive years) varies greatly by age. If we want to characterize fertility with a single number, we need a way to summarize the overall picture. The measure that is typically used for this purpose is the TFR, and it can be regarded simply as the sum of the age-specific fertility rates for each year of age between 15 years and 44 (or 49) years, inclusive. TFR is typically described as the number of births expected per woman for an imaginary a cohort of women moving through their reproductive lifetimes (generally taken as ages 15-44 or 15-49 years). The expectation is based on the current fertility rates at each age in a given year.

The next slide shows an example of such a calculation.



Age-specific fertility rates are usually calculated for 5-year age intervals, so that is the starting place for calculating the TFR. Suppose as shown on the slide, there were 5,000 births to 48 thousand women aged 15-19 years, 6,000 births to 44 thousand women age 20-24, 5,000 births to 39,000 women age 25-29 years, and so on. So, the average fertility rate for women aged 15-19 years old in that year was $5,000/48,000 = 0.104$, or 104 per 1,000 women-years.

The average fertility rate for women 20-24 years old in that year was $6,000/44,000 = 136$ per 1,000 women years, etc.

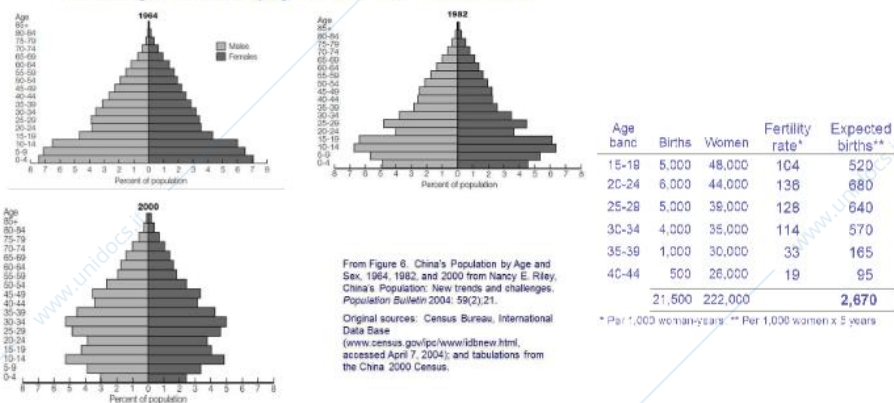
Demography and aging :

Age band	Births	Women	Fertility rate*
15-19	5,000	48,000	0.104
20-24	6,000	44,000	0.136
25-29	5,000	39,000	0.128
30-34	4,000	35,000	0.114
35-39	1,000	30,000	0.033
40-44	500	26,000	0.019
	21,500	222,000	2.67

* Per woman-year

In this table the fertility rates are shown per 1,000 women per year. If these age-specific fertility rates were to stay that way for the next 30 years, a cohort of 1,000 women age 15 years old today would be expected to have about 104 babies at age 15, 104 babies at age 16, 104 babies at age 17, 104 babies at age 18, and 104 babies at age 19, or a total of $5 \times 104 = 520$ babies by the time the women reached their 20th birthday. As these women moved through the five years from age 20 to 24 years, the women would have another 136 babies each year, or $5 \times 136 = 680$ babies by the women's 25th birthday. During their next five years (ages 25-29 years of age) the women would have $5 \times 128 = 640$ babies, and then 570, 165, and 95 babies, respectively, during the next three 5-year intervals. Adding these numbers up, we get 2,670 babies born to the 1,000 women, or 2.67 babies per woman, giving us the total fertility rate (if you calculate without rounding the intermediate results you will obtain 2.68, which is more nearly precise).

China's Age Distribution by age and sex, 1964, 1982, and 2000

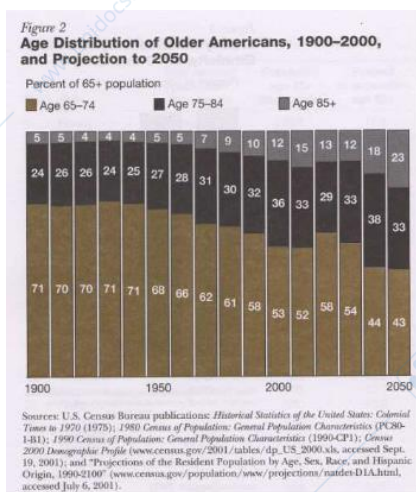


From Figure 8. China's Population by Age and Sex, 1964, 1982, and 2000 from Nancy E. Riley, China's Population: New trends and challenges, Population Bulletin 2004: 59(2):21.
Original sources: Census Bureau, International Data Base (www.census.gov/ipc/www/idbnew.html, accessed April 7, 2004); and tabulations from the China 2000 Census.

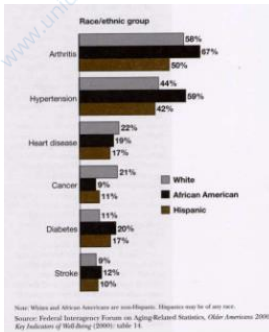
This Figure shows three population pyramids for China. The constrictions at ages 15-24 years in 1964, which are echoed in ages 35-44 year in 1982 likely reflect the impact of World War II and the Japanese occupation. The 20-24-year-olds in 1982, whose numbers are severely curtailed, consists of people born during "The Great Leap Forward", described on the slide about fertility in China. The widening of the 1982 pyramid at younger ages is partly due to a catch-up phenomenon of families having the babies which they would have had during 1958-1962. In the 2000 pyramid we see the "echoes," one generation later, of the constriction from the Great Leap Forward and of the subsequent rebound. Meanwhile the 1982 and 2000 pyramids, with their narrow bases, show the impact of China's successful though in some respects controversial population policies and the aging of the population that is occurring.



This Figure shows the number of people aged 65 and older in China in 1990 and projected for 2000, 2010, and 2020. Even though China is still in many ways a developing country, improved public health has extended lifetimes. With its large population size, increases in life expectancy imply substantial growth in the older population, which will nearly double between 2000 to 2020.



This graph shows a series of stacked bars with the age distribution of older Americans (age 65 years and above) from 1900-2000 and projected to 2050. The graph indicates how the age distribution among seniors has moved up the age ladder. In 1900, most seniors (65 years and older) were younger than age 75, and only 5% were 85+ years. By 2050, "young seniors" (age 65-74) will be a minority of all seniors, while nearly one-in-four will be 85+. The "greying" of American society has been underway since the middle of the 20th century and is transforming the nature of society in many respects. Older people vote differently from younger people, older people have different health conditions and concerns, older people have more expensive health problems than younger people (e.g., one-in-four persons age 80 and older have Alzheimer's disease), and older people for the most part are living on retirement assets and government programs. The dependency ratio is the number of children and adults over 65 to the number of people of working age, who provide much of the financial and instrumental support for the young and the old. As the population ages, the dependency ratio will increase. Even if the retired population has substantial financial assets on which to live, it still takes people to provide the services they need. We can anticipate shortages even more severe than the current nursing shortage unless we greatly improve the educational preparation of young people and/or increase immigration.



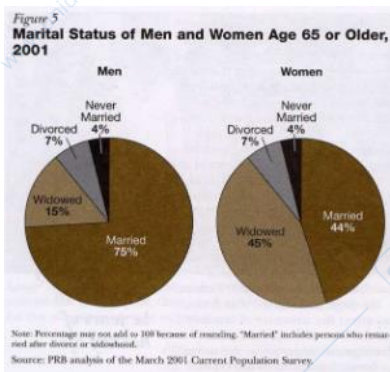
This Figure illustrates the high prevalence of chronic medical conditions among Americans aged 65 and above as well as substantial differences across three ethnic groups. Ethnicity refers to groups of people with shared culture, language, religion, and/or geographical origin. Many countries have multiple ethnic groups. In the United States the term “race” is often used to classify people based on skin colour and several other physical features. In the United States that distinction has been used as a basis for enslaving millions of African Americans, killing or dispossessing American Indians, and discriminating against Asians and others. A biological rationale for these actions was constructed on the foundation that people belonging to different “races” were fundamentally different. This view has been largely discredited, but race remains very much a reality because of its connection to social, economic, and political factors as well as cultural and historical experience. Disparities in health status for different ethnic groups are a major public health concern.

Population analysis by gender: SEX RATIO

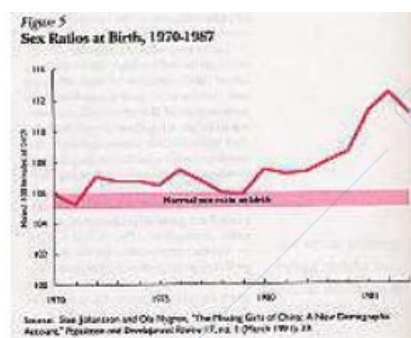


This graph shows the age and sex profile of the United Arab Emirates in 2000.

Note the dramatic population imbalance in the among adults age 40-59 years old, representing the men who immigrated from neighbouring countries and Asia decades earlier to work in the oil fields and in construction. The government discouraged the men’s bringing their families, to reduce the probability that they would settle in the UAE. As you can imagine, such marked imbalances can produce interesting social dynamics.

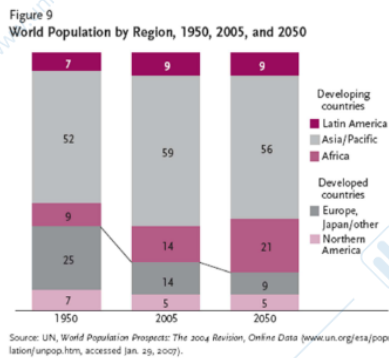


This graph has pie charts showing the distribution of marital status of men and women age 65 and above, in the U.S. in 2001. What do we see in this slide? 75% of men in this age group are married, compared to only 44% of women. How can that be? Whom are the men marrying. Since men typically marry women younger than themselves, some of these men have married women younger than age 65, who are not included in the graph. Also, of course, there are more women than men in that age group, so the same number of married couples produces a larger proportion of men who are married than of women who are married. The sex ratio among people over age 65 in the United States is considerably below 100, i.e., fewer than 100 males for 100 females.

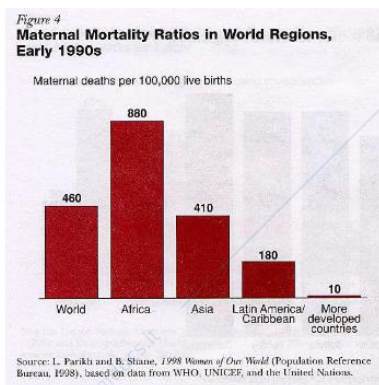


This graph shows sex ratios at birth, from 1970-1987, in China. Sex ratios in most periods and most countries we have data for are generally 105-106 (per 100 females) at birth and fall gradually with age. In the 1964 census in China, it was 103.8 at birth and 105.3 at one year of age (Johansson and Nygren, 1991).

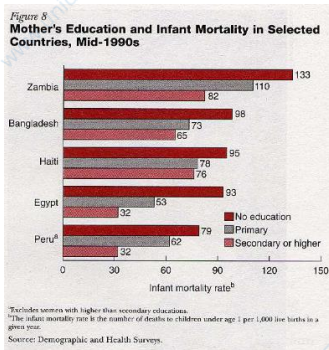
In this graph we see that the sex ratio at birth rose in the mid-1980s, rising to an exceptionally high level. What is happening here? Several explanations have been considered. China introduced a one-child policy in 1979, and there is a strong cultural preference for males. One effect was underreporting of female births so they would not count against the one-child quota per couple. Many of the unreported girls are apparently given away for adoption (Johansson and Nygren, 1991). Another part of the explanation may be higher mortality for female infants who are not reported, due to deliberate infanticide or relative neglect of female infants. The potential exists for a lot of Chinese men who will not be able to find Chinese women.



Along with the expansion of the world's population during the second half of the 20th century has come a dramatic shift in its global distribution. Asia and the Pacific, where most of the world's population live, have increased their dominance though their share is projected to decline modestly by mid-21st century. Europe's share of world population declined from 25% to 14% from 1950 to 2005 and is projected to decline to 9% by mid-21st century. Meanwhile, in spite of the AIDS epidemic Africa's share is projected to increase to 21% from 9% in 1950 and 14% in 2005. The Americas' share of world population has remained stable at 14%, but with a shift from Northern America to Latin America. In addition to the changes shown in the figure, the populations of Europe and especially Northern America are increasingly composed of immigrants from Africa, Latin America, and Asia.

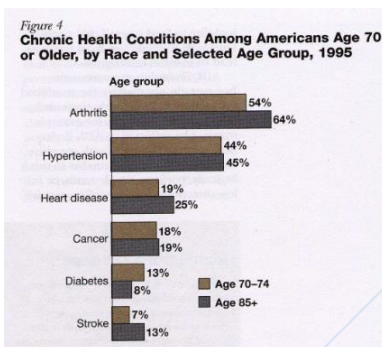


This Figure shows maternal mortality ratios in world regions, in the early 1990s. In Africa, the figure was almost twice as high as in the world as a whole. Maternal mortality is something that we know through public health and medicine how to prevent. In the developed countries, maternal mortality was 10 per 100,000 live births, one-eighteenth the rate in Latin America, less than a fortieth the rate in Asia. These dramatic disparities are a challenge to public health to which we will return to at the end of the course, when we take up the Role of Epidemiology in Public Health.



The status of women is a major determinant of many aspects of public health, including childhood mortality. This slide shows the infant mortality rates according to the education of the mother in various developing countries. In every country the infant mortality rate is highest for uneducated mothers and lowest for mothers with secondary education. But there are also large differences across countries at all educational levels.

Ethnicity



This graph shows the prevalence – that is, the percentage of the population who are afflicted – of six chronic conditions [arthritis, hypertension, heart disease, cancer, diabetes, and stroke] for two age groups: 70-74 years and 85+ years in 1995. Most of these conditions are more prevalent in the older age group, but what is perhaps most significant in the graph is the substantial prevalences of older Americans who have arthritis (over half), hypertension (nearly half), heart disease or a history of cancer (about one-in-five for each), diabetes and history of stroke (about one-in-ten for each). Since the population of elderly is expanding rapidly, it is likely that we will see much larger numbers (though not necessarily larger percentages) of older people with chronic health conditions. We cannot automatically conclude that when today's 50-75-year-olds are 70-95 they will experience chronic health conditions at these percentages, since people who in 1995 were older than age 70 years were born before 1925, and therefore had different life experiences and exposures than people who will pass age 70 during the next two decades. But it is likely that the prevalence of these conditions will be at least as great, since prevention of arthritis and hypertension is not on the horizon, whereas survival from heart disease and cancer will probably increase. The obesity epidemic will probably contribute to higher rates of diabetes and probably heart disease and cancer – if survival improves, the prevalence of these conditions will increase.