USGCRP Climate and Health Assessment

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Executive Summary

Climate change is a significant threat to the health of the American people. The Third National Climate Assessment confirmed the evidence for human-induced climate change and described how impacts are increasing nationwide. Rising carbon dioxide concentrations, and the resulting increases in temperature, changes in precipitation, increases in the frequency and intensity of extreme weather events, and sea level rise endanger our health by affecting our food and water sources, the air we breathe, the weather we experience, and our interactions with the built and natural environments. As the climate continues to change, the risks to human health continue to grow.

Current and future climate impacts expose more people in more places to public health threats. Already in the United States, we have observed climate-related increases in exposure to elevated temperatures; increases in the frequency, severity, or duration of certain extreme weather events; degraded air quality; diseases transmitted through food, water, and disease vectors (such as ticks and mosquitoes); and stresses to our mental health and well-being. Almost all of these threats are expected to worsen with continued climate change. Some of these health threats will occur over longer time periods, or at unprecedented times of the year, or will expose people in regions of the country that have not previously experienced these threats.

Every American is vulnerable to the health impacts associated with climate change. Increased exposure to multiple health threats, together with changes in sensitivity and the ability to adapt to those threats, increases a person’s vulnerability to climate-related health effects. The impacts of climate change on human health interact with changes in underlying health, demographic, and socioeconomic factors. Through the combined influence of these factors, climate change exacerbates and accelerates some existing health threats and creates new public health challenges. While all Americans are at risk, some populations of concern are disproportionately vulnerable, including those with low income; some communities of color; those with limited English proficiency; immigrant groups; Indigenous peoples; children and pregnant women; older adults; certain occupational groups; persons with functional disabilities; and persons with pre-existing or chronic medical conditions.

In recent years, our understanding of how climate change increases risks to human health has advanced significantly. Even so, our ability to evaluate, track, and project health effects varies across climate impacts. For instance, health outcomes differ in terms of whether complete, long-term datasets exist that allow us to quantify observed changes, and whether existing models are able to project impacts at the timescales and geographic scales of interest. Differences also exist in the metric we are able to observe or project across different health outcomes. For some, we are only able to describe changes in risk or exposure, while in others we can describe changes in actual health outcomes (such as the number of new cases of a disease or an increase in deaths).
This scientific assessment builds on the National Climate Assessment and reviews and synthesizes new literature on the impacts of climate change on human health in the United States. Each chapter characterizes the strength of the scientific evidence for a given climate-health exposure pathway or “link” in the causal chain between a climate change impact and its associated health outcome. Our understanding of climate-related health impacts has been strengthened and expanded towards a more definite description of climate-related health burdens in the United States. This assessment’s findings represent an improvement in scientific confidence in the link between climate change and threats to public health, and includes recognition of populations of concern, a broad range of health impacts, and identification of emerging issues. These considerations provide needed context for understanding Americans’ changing health risks. Acknowledging the rising demand and necessity for data that can be used to characterize how climate change affects health, this assessment highlights analyses that quantify health impacts. The findings, which synthesize key contributions to the scientific knowledge that allows us to understand, project, and respond to future climate change health threats, underscore the significance of the growing risk climate change poses to human health.

How Does Climate Change Affect Human Health?

The influences of weather and climate on human health are significant and varied. Exposure to health hazards related to climate change and variability affects different people and different communities to different degrees. While often assessed individually, exposure to multiple climate change threats can occur simultaneously with compounding or cascading health impacts (see Figure ES1).

With climate change, the frequency, severity, and even the location of weather and climate phenomena like rising temperatures, heavy rains and droughts, and some other kinds of severe weather are changing. This means that areas that already experience health-threatening weather and climate phenomena, such as severe heat or hurricanes, are likely to experience worsening impacts, such as higher temperatures and more severe storm surge and wind speeds. It also means that some areas will experience new climate-related health threats. For example, areas previously unaffected by toxic algal blooms or waterborne diseases because of cooler water temperatures may face these hazards in the future as increasing water temperatures allow the organisms that cause these health risks to thrive. Even areas that currently experience these health threats may see a shift in the timing of the seasons that pose the greatest risk to human health.

Climate change can therefore affect human health in two main ways: first, by changing the severity or frequency of health problems that are already affected by climate and weather factors; and second, by creating unprecedented or unanticipated health problems or health threats in places where they have not previously occurred.
Figure ES1: Climate Change and Health

Caption: Conceptual diagram illustrating the exposure pathways by which climate change affects human health. The central blue pathway includes selected examples of climate drivers—the pathways by which humans are exposed to health threats from those drivers, and the resulting health outcomes. The orange path on the left indicates examples of environmental and biological conditions not necessarily driven by climate change that can affect human vulnerability to health impacts of climate change. The green path on the right indicates social determinants of health that also affect human vulnerability to health impacts of climate change. The diagram also shows that climate drivers can affect health outcomes by influencing the state of non-climate stressors and social determinants of health.
Temperature-Related Death and Illness

Increasing concentrations of greenhouse gases lead to a warming of both average and extreme temperatures. This is expected to lead to a decrease in deaths from cold and an increase in deaths and illness from heat (see Figure ES2), particularly for a number of communities especially vulnerable to these changes, such as children, the elderly, and disadvantaged groups. Days that are hotter than normal in the summer or colder than normal in the winter both cause increased levels of illness and death by compromising the body’s ability to regulate its temperature or by inducing direct or indirect cardiac complications. Loss of internal temperature control can result in a cascade of illnesses, including heat cramps, heat exhaustion, heatstroke, and hyperthermia in the presence of extreme heat, and hypothermia and frostbite in the presence of extreme cold. Temperature extremes can also worsen chronic conditions such as cardiovascular disease, respiratory disease, cerebrovascular disease, and diabetes-related conditions. Prolonged exposure to high temperatures is associated with increased hospital admissions for cardiovascular, kidney, and respiratory disorders.

Future Increases in Temperature-Related Deaths

Key Finding 1: Future climate warming could lead to thousands to tens of thousands of additional deaths each year from heat in the summer, as calculated by extrapolating statistical relationships and without considering potential adaptive changes [Very Likely, High Confidence]. Climate warming will also lead to a decrease in deaths from cold in the winter [Very Likely, Medium Confidence], but this reduction in deaths is projected to be smaller than the increase in summertime heat-related deaths in most regions [Likely, Medium Confidence].

Illness and Deaths are Related to Deviations from Seasonal Average

Key Finding 2: Days that are hotter than normal in the summer or colder than normal in the winter are both associated with increased illness and death. While large health effects are observed for extreme temperature events, mortality effects are also seen for smaller deviations of even a few degrees from seasonal averages, and small deviations from average temperature occur much more frequently than extreme events. Due to climate change, more hot days and fewer cold days are expected in the future. [Very Likely, High Confidence]

Changing Tolerance to Extreme Heat

Key Finding 3: An increase in population tolerance to extreme heat [Very Likely, High Confidence], but not extreme cold, has been observed over time. This could be related to increased use of air conditioning, improved social responses, and/or physiological acclimitization [Likely, Medium Confidence]. Including this adaptation trend in human health projections will reduce but not eliminate the increase in future deaths from heat [Likely, Low Confidence].
Some Populations at Greater Risk

Key Finding 4: Elderly persons and people working outdoors have a higher risk of dying due to increasing frequency, intensity, and duration of future heat and heat waves. Children and working age adults have increased vulnerability to heat-related illness. The socially isolated, economically disadvantaged, some communities of color, and those with chronic illnesses are also especially vulnerable to death or illness. [High Confidence]

Figure ES2. Projected Changes in Deaths in U.S. Cities by Season

Caption: This figure shows the projected increase in deaths due to warming in the summer months (hot season, April-September), the projected decrease in deaths due to warming in the winter months (cold season, October-March), and the projected net change in deaths for the 209 U.S. cities examined. These results are based on the statistical approach of Schwartz et al. (2014) using the GFDL-CM3 and MIROC5 climate models.
Air Quality Impacts
Changes in the climate affect the air we breathe both indoors and outdoors. The changing climate has modified weather patterns, which in turn have influenced the levels and location of outdoor air pollutants such as ground-level ozone (see Figure ES3) and fine particulate matter. Increasing CO₂ levels will also promote the growth of plants that release airborne allergens (aeroallergens). Finally, these changes to outdoor air quality and aeroallergens may also affect indoor air quality as both pollutants and aeroallergens infiltrate homes and offices. Poor air quality, whether outdoors or indoors, can negatively affect the human respiratory and cardiovascular systems. Higher pollen concentrations and longer pollen seasons can increase allergic sensitization and asthma episodes and thereby limit productivity at work and school.

Exacerbated Ozone Health Impacts

Key Finding 1: Changes to the climate will tend to make it harder for any given regulatory approach to reduce ground-level ozone pollution in the future as meteorological conditions become increasingly conducive to forming ozone over most of the United States. Unless offset by additional emissions reductions, these climate-driven increases in ozone will cause premature deaths, hospital visits, lost school days, and acute respiratory symptoms. [Likely, High Confidence]

Worsened Allergy and Asthma Conditions

Key Finding 2: Changes in climate, specifically rising temperatures, increasing precipitation, and increasing atmospheric carbon dioxide, are expected to contribute to increasing levels of some airborne allergens and associated increases in asthma episodes and other allergic illnesses compared to a future without climate change. [High Confidence]
Figure ES3. Projected change in average daily maximum temperature, seasonal average maximum daily 8-hr ozone, and ozone-related premature deaths in 2030

Caption: The air quality response to climate change can vary substantially by region across scenarios. Two downscaled global circulation model projections estimate increases in average daily maximum temperatures of 1°C to 4°C (1.8°F to 7.2°F) and corresponding 1 to 5 parts per billion increases in average daily 8-hour maximum ozone at 2030 throughout the continental United States. Unless offset by additional emissions reductions, this “climate penalty” of increased ozone concentrations due to climate change would lead to tens to thousands of additional ozone-related illnesses and premature deaths per year. (Figure source: Fann et al. 2014)
Vectorborne Diseases

Vectorborne diseases are illnesses that are transmitted by vectors, such as mosquitoes, ticks, and fleas. These vectors can carry infective pathogens such as viruses, bacteria, and protozoa, which can be transferred from one host (carrier) to another. The seasonality, distribution, and prevalence of vectorborne diseases are influenced significantly by climate factors, primarily high and low temperature extremes and precipitation patterns. Climate change is likely to have both short- and long-term effects on vectorborne disease transmission and infection patterns, affecting both seasonal risk and broad geographic changes in disease occurrence over decades (See Figure ES4). While climate variability and climate change both alter the transmission of vectorborne diseases, they will likely interact with many other factors, including how pathogens adapt and change, human susceptibility to infection, changing ecosystems, and human demographics and behavior. These complex interactions make it difficult to predict the effects of climate change on vectorborne diseases.

Changing Distributions of Vectors and Vectorborne Diseases

Key Finding 1: Climate change is expected to alter the geographic and seasonal distributions of existing vectors and vectorborne diseases [Likely, High Confidence].

Earlier Tick Activity and Northward Range Expansion

Key Finding 2: Ticks capable of carrying the bacteria that cause Lyme disease and other pathogens will show earlier seasonal activity and a generally northward expansion in their habitat range in response to increasing temperatures associated with climate change [Likely, High Confidence]. Longer seasonal activity and expanding geographic range of these ticks may increase the risk of human exposure to ticks [Low Confidence].

Climate-driven Mosquito-borne Disease Dynamics

Key Finding 3: Rising temperatures, changing precipitation patterns, and a higher frequency of some extreme weather events associated with climate change will influence the distribution, abundance, and infection rate of mosquitoes that transmit West Nile virus and other pathogens by altering habitat availability and mosquito and viral reproduction rates [Extremely Likely, High Confidence]. Alterations in the distribution, abundance, and infection rate of mosquitoes may increase human exposure to bites from infected mosquitoes, which may increase risk for human disease [Low Confidence].

Climate and Non-climate Factors Determine Human Vulnerability

Key Finding 4: Non-climate factors that affect vulnerability to vectorborne disease (such as age, gender, socioeconomic status, geography, and occupation) also influence risk for disease occurrence [High Confidence].
Emergence of New Vectorborne Pathogens

Key Finding 5: Climate change will interact with other driving factors (such as travel-related exposures or evolutionary adaptation of invasive vectors and pathogens) to influence the emergence or re-emergence of vectorborne pathogens [High Confidence].

Figure ES4: Changes in Lyme Disease Case Report Distribution.

Caption: Maps show the reported cases of Lyme disease in 1996 and 2013 for the areas of the country where Lyme disease is most common (the Northeast and Upper-Midwest). Both the distribution and the numbers of cases have increased. (Figure source: CDC 2014)
Water-Related Illnesses

Across most of the United States, climate change is expected to affect fresh and marine water sources in ways that will increase people’s exposure to contaminants that cause illness (see Figure ES5). Water-related illnesses can be caused by pathogens, such as bacteria, virus, and protozoa; toxins produced by certain harmful algae and cyanobacteria; and chemicals introduced into the environment by human activities. Certain climate and weather factors enhance the growth, survival, spread, and virulence, or toxicity, of water-related pathogens and toxins, which make them more likely to cause disease. Exposure occurs through ingestion, inhalation, or direct contact with contaminated drinking or recreational water and through consumption of fish and shellfish. Whether or not illness results from exposure to contaminated water is dependent on a complex set of factors, including human behavior and other social determinants of health. Water resource, public health, and environmental agencies in the United States provide extensive public health safeguards, such as water quality monitoring and issuing advisories, to reduce risk of exposure and illness even if local water sources become contaminated.

Seasonal and Geographic Expansion of Waterborne Illness Risk

Key Finding 1: Increases in both coastal and inland water temperatures associated with climate change will expand the seasonal windows of growth [Very Likely, High Confidence] and the geographic range of suitable habitat [Likely, High Confidence] for naturally occurring pathogens and toxin-producing harmful algae. These changes are projected to increase the risk of exposure to waterborne pathogens and algal toxins that can cause a variety of illnesses [Medium Confidence].

Exposure Risk from Extreme Precipitation Events

Key Finding 2: Recreational waters and sources of drinking water will be compromised by increasingly frequent and intense extreme precipitation events [High Confidence]. Surface runoff and flooding associated with heavy precipitation and storm surge events increase pathogen loads originating from urban, agricultural, and wildlife sources and promote blooms of harmful algae in both fresh and marine waters. Greater pathogen or algal toxin loading in drinking and recreational water sources following an extreme weather event will increase risk of human exposure to agents of water-related illness [Medium Confidence].

Water Infrastructure Failure or Damage

Key Finding 3: Increases in some extreme weather events and storm surge will increase the risk of failure of, or damage to, water infrastructure for drinking water, wastewater, and stormwater [Medium Confidence]. Aging infrastructure is particularly susceptible to failure. A breakdown in water infrastructure would contribute to increased risk of exposure to water-related pathogens, chemicals, and algal toxins.
Figure ES5: Links between Climate Change, Water Quantity and Quality, and Human Exposure to Water-related Illness

Caption: Precipitation and temperature changes affect fresh and marine water quantity and quality of urban, rural, agriculture and wildlife runoff, which in turn affects human exposure to waterborne illnesses, primarily through drinking water, recreational water, and contaminated seafood.
Food Safety, Nutrition, and Distribution

A safe and nutritious food supply is a vital component of food security. Systems and processes related to food safety, nutrition, and production are inextricably linked to their physical and biological environment. There are two overarching means by which increasing carbon dioxide (CO2) and climate change alter safety, nutrition, and distribution of food (see Figure ES6). The first is associated with rising global temperatures and the subsequent changes in weather patterns and extreme climate events. Current and anticipated changes in climate and the physical environment have consequences for contamination, spoilage, and the disruption of food distribution. The second is that higher concentrations of CO2 stimulate carbohydrate production and plant growth, but lower the levels of protein and essential minerals in a number of widely consumed crops, including wheat, rice and potatoes, with potentially negative implications for human nutrition.

Increased Risk of Foodborne Illness

Key Finding 1: Although there are many practices to safeguard food in the United States, climate change, including rising temperatures and changes in weather extremes, is expected to intensify pathogen and toxin exposure [Likely, High Confidence], increasing the risk, if not the actual incidence, of foodborne illnesses [Medium Confidence].

Chemical Contaminants in the Food Chain

Key Finding 2: Elevated sea surface temperatures and increases in certain weather extremes associated with climate change will increase human exposure to water contaminants in food [Likely, Medium Confidence]. Climate change will also alter the incidence and distribution of pests, parasites, and microbes [Very Likely, High Confidence], which will lead to increases in the use of pesticides for crop protection, animal agriculture, and aquaculture. Increased use of pesticides may result in increased human exposure to chemical contaminants in the food chain [High Confidence].

Rising Carbon Dioxide Lowers Nutritional Value of Food

Key Finding 3: Rising atmospheric carbon dioxide will continue to lower the nutritional value of most food crops, including wheat and rice, and can also reduce the concentration of essential minerals in a number of crop species. [Very Likely, High Confidence]
Extreme Weather Limits Access to Safe Foods

Key Finding 4: Increases in the frequency or intensity of some extreme weather events associated with climate change may increase disruptions of food distribution by damaging existing infrastructure or slowing shipments. These impediments may lead to food damage, spoilage, or contamination, which may limit availability and access to safe and nutritious food. [Medium Confidence]

Figure ES6: Farm to Table: The Potential Interactions of Rising CO₂ and Climate Change on Food Safety

Caption: The food system involves a network of interactions with our physical and biological environments as food moves from production to consumption, or from “farm to table.” Rising CO₂ and climate change will affect the quality and distribution of food, with subsequent effects on food safety and nutrition.
Extreme Weather
Climate change has already resulted in a shift in the frequency, intensity, and duration of certain extreme events (see Figure ES7). Projections show that there will be an increase in the occurrence and severity of some extreme weather (such as the frequency and intensity of heavy rainfall events) in the coming century, while for other extremes the links to climate change are more uncertain. Health hazards associated with extreme events can result in death, injury, disease, and other negative effects on human physical, mental, and social well-being. The severity and extent of health effects associated with extreme weather events depend on the unique human, societal, and environmental circumstances at the time and place where events occur. Extreme events may result in direct health impacts, such as drowning or injury during a hurricane (see Figure ES7). Other health impacts may occur after the event as a result of damage to property, destruction of assets, loss of infrastructure and public services, social and economic disruption, environmental degradation, and other factors.

Changes in Exposure Risk
Key Finding 1: Climate change may increase exposure to health hazards associated with projected increases in the frequency and/or intensity of extreme precipitation, hurricanes, coastal inundation, drought, and wildfires in some regions of the United States [Medium Confidence]. Adverse health outcomes associated with exposure to extreme events include death, injury, or illness; exacerbation of underlying medical conditions; and adverse effects on mental health.

Other Factors Influence Health Impacts
Key Finding 2: The character and severity of health impacts from extreme events depend not only on the frequency or intensity of the extremes themselves but also on a population’s exposure, sensitivity, and adaptive capacity. Many types of extreme events can cause loss of essential infrastructure, such as water, transportation, and power systems that are required to safeguard human health. [High Confidence]

Certain Populations Are More Vulnerable
Key Finding 3: Key risk factors that individually and collectively shape a population’s vulnerability to health impacts from extreme events include age, health status, socioeconomic status, race/ethnicity, and occupation. [High Confidence]
Figure ES7: Estimated Deaths and Billion Dollar Losses from Extreme Events in the United States 2004-2013

Caption: This figure provides 10-year estimates of fatalities related to extreme events from 2004-2013 (NOAA 2015), as well as estimated economic damages from a few weather and climate disaster events with losses exceeding $1 billion (see Smith and Katz 2013 to understand how total losses were calculated). These statistics are indicative of the human and economic costs of extreme weather events over this time period. Climate change will impact the frequency, intensity and geographic distribution of some of these extremes (Melillo et al. 2014), which has consequences for people's exposure to health risks from extreme events. Trends and future projections for some extremes, including tornadoes, lightning, and wind storms are still uncertain.
Mental Health and Well-Being

The effects of global climate change on mental health and well-being are an integral part of the overall climate-related human health impacts. Mental health consequences of climate change range from minimal stress symptoms to clinical disorders (such as anxiety, depression, post-traumatic stress, and suicidality) and from interpersonal violence to group conflict. They also include effects on the everyday life, perceptions, and experience of individuals and communities attempting to understand and respond appropriately to climate change and its implications. Anything that affects human health and welfare has the potential to impact mental health and well-being. Therefore, the adverse mental health impacts of climate change are likely to be wide-ranging, stressful, and cumulative (see Figure ES8).

Mental Health Consequences of Exposure to Disasters

Key Finding 1: Many people exposed to climate-related disasters experience stress and serious mental health consequences. Depending on the type of the disaster, these serious mental health consequences include significant symptoms of post-traumatic stress disorder (PTSD), depression, and general anxiety, which often occur at the same time. The majority of affected people recover over time on their own, although a significant proportion of exposed individuals develop chronic levels of psychological dysfunction. [Very High Confidence]

Specific Groups of People Are at Higher Risk

Key Finding 2: Specific groups of people are at higher risk for distress following climate-related events. These groups include children, the elderly, and women (especially pregnant and post-partum women), people with pre-existing mental illness, low-income persons, first-responders, and people who are homeless. Communities that rely on the natural environment for sustenance and livelihood and populations living in areas most susceptible to specific climate change events are at increased risk for adverse mental health outcomes. [High Confidence]

The Threat of Climate Change

Key Finding 3: The threat of climate change, the perceived direct experience of climate change, and changes to one’s local environment can result in substantial adverse mental health outcomes and social impacts for the American public. Virtually all Americans are exposed to the threat of climate change and to events attributed to the impacts of climate change through frequent multi-media coverage. [High Confidence]

Extreme Heat May Increase Risks for People with Mental Illness

Key Finding 4: People with mental illness, especially those who take certain prescription medications to treat their illnesses, are at higher risk for poor physical and mental health due to extreme heat. Increases in extreme heat will have an impact on the incidence of disease and
death of people with mental illness. Significant segments of people with mental illnesses who are most vulnerable to extreme heat, such as the elderly, are also taking medication that impairs the body’s ability to regulate heat and therefore have increased vulnerability to the effects of heat. [Very High Confidence]

**Figure ES8. The Impact of Climate Change on Physical, Mental, and Community Health.**

The Impact of Climate Change on Physical, Mental, and Community Health

**Caption:** At the center of the diagram are human figures representing adults, children, older adults, and people with disabilities. The left circle depicts climate impacts including heat, wildfires, sea-level rise, storms, and drought. The right circle shows the three interconnected health domains, Medical and Physical Health, Mental Health, and Community Health, that will be affected by climate impacts.
Climate-Health Risk Factors and Populations of Concern

Climate change is already causing and will continue to result in a range of health impacts across different population groups in the United States. The vulnerability of any given group is a function of its sensitivity to climate-related health impacts, its exposure to those risks, and its capacity for responding to or coping with climate variability and change (see Figure ES9). Particularly vulnerable groups of people, described here as populations of concern, include those with low income, communities of color, those with limited English proficiency and immigrant groups, Indigenous peoples, children and pregnant women, older adults, certain occupational groups, persons with functional disabilities, and persons with biologically determined vulnerability, such as pre-existing or chronic medical conditions. Characterizations of vulnerability should consider how populations of concern experience disproportionate, multiple, or complex risks to their health and well-being.

Vulnerability Varies Across Individuals, Time Scales, and Places

Key Finding 1: Across the United States, people and communities differ in their exposures, their inherent sensitivity, and their adaptive capacity that enables them to respond to and cope with climate change related health threats. Vulnerability to climate change varies across time and geographic areas, across communities, and among individuals within communities. [Very High Confidence]

Climate Factors Interact with Non-Climate Factors to Increase Health Risk

Key Finding 2: Climate change related health risks interact with some of the same non-climate factors that increase the risk of poor health generally. Non-climate factors, such as those related to demographic changes, socioeconomic factors, and pre-existing or chronic illnesses, may amplify, moderate, or otherwise influence climate-related health effects, particularly when they occur simultaneously or close in time or space. [High Confidence]

Increased Vulnerability to Climate-Related Health Impacts is Widespread Across Ages and Stages of Life

Key Finding 3: People experience different vulnerabilities at different ages and life stages. For example, the very young and the very old are particularly sensitive to climate-related health impacts. [High Confidence]

Mapping Tools and Vulnerability Indices Help to Identify Where and for Whom Climate Health Risks Are Greatest

Key Finding 4: The use of geographic data allows for more sophisticated mapping of risk factors and social vulnerabilities to identify and protect specific locations and groups of people. [Medium Confidence]
Figure ES9. Determinants of Vulnerability

Caption: Defining determinants of vulnerability to health impacts, including exposure, sensitivity, and adaptive capacity (Figure source: adapted from Turner et al. 2003)
References


