Resurgent outbreaks of infectious diseases are sickening thousands, and the causes are societal

By Melinda Wenner Moyer
Photographs by Brian Day
MIDTOWN DETROIT’S Cass Corridor neighborhood has new construction, as well as a population of sick and homeless people.
It was January 8, 2018, and Detroit was in the midst of the largest hepatitis A outbreak in the city’s history. Since August 2016 the disease has stretched across southeastern Michigan, sickening more than 770 people, and it has become the biggest such outbreak in the U.S. since a vaccine became available in 1995. Cases were still mounting as this article went to press. And Michigan’s situation is not unique. Hepatitis A, caused by a virus, has infected 700 people in California—primarily San Diego—between November 2016 and the end of February, and parts of Utah, Colorado, Wyoming and Kentucky have been hit hard, too. The extent is unusual. In many other cases, the illness infects people in small, short-lived, food-associated clusters—sick restaurant workers contaminate food and infect a dozen or so customers. Sustained person-to-person spread like this is rare.

The severity of this epidemic also stands out. An estimated 81 percent of those infected in Michigan have been hospitalized subsequent to liver damage, and 25 have died, as of early March. That is much worse than the typical hospitalization rates, which hover between 11 and 22 percent, according to a 2017 report optimistically entitled *Progress Toward Viral Hepatitis Elimination in the United States*, penned by researchers at the U.S. Centers for Disease Control and Prevention. “To be making rounds on individuals who have been previously healthy but are now in liver failure is really staggering,” says Stuart Gordon, a liver specialist at Henry Ford Hospital in Detroit. “We are seeing a much more severe outbreak than we’ve ever seen before.”

Other infections have also been tearing through U.S. cities. In 2017 New York City diagnosed a record number of cases of Legionnaires’ disease—65 percent more than in 2016—a serious pneumonia caused by bacteria growing in water systems. In San Francisco, rates of gonorrhea, a sexually transmitted infection that has become worryingly resistant to antibiotics, increased 22 percent between 2015 and 2016; in fact, the incidence of all three nationally reported sexually transmitted infections—chlamydia, gonorrhea and syphilis—have recently reached record highs throughout the country. The list goes on: Cases of cyclosporiasis, an intestinal illness caused by a parasite in drinking water and swimming pools, nearly doubled between 2016 and 2017. Rates of hepatitis C, another virus that damages the liver and one that often becomes chronic, have nearly tripled over the past five years.

**DEAN CARPENTER ZIGZAGS HIS WAY** through a row of men seated in hard plastic chairs at Detroit’s Tumaini Center, a crisis support organization for the chronically homeless in Michigan’s biggest city. The center has no beds, so some men have been living in those chairs for weeks, even years, while case workers try to secure them housing. Carpenter, the center’s nurse practitioner, has seen patients with many ailments over the years: scabies, trench foot and, most recently, hepatitis A, which he is on a mission to vanquish. “You want a hepatitis A vaccine? There’s an outbreak in Detroit,” Carpenter says quietly to one older man. The man nods, rises and follows Carpenter to the conference room, where a second nurse practitioner and a team of Michigan State University medical students wait with needles.

**IN BRIEF**

Rising rates of hepatitis A, Legionnaires’ disease and other scourges carried by viruses, bacteria and parasites are scarring U.S. cities. Infectious diseases, once thought to be on the wane, are making a comeback, driven by widening economic inequality and microbe-vulnerable buildings. Not only the poor but the well off are at risk, as disease transmission crosses lines of health and wealth.
These surging infections in the U.S. are not what the medical world expected. Infectious diseases are less of a threat in this country than they were a century ago, thanks to mass vaccination, improved sanitation, and scientific advances in diagnostics, treatment and epidemiology. Rates of HIV and tuberculosis are still continuing to decline overall. But some infections are making a strong comeback in America, and researchers worry that the effects of the diseases could be more devastating now because the country has a more aged, chronically ill and vulnerable population. Infections rarely seen in the U.S. are also ripe for emergence, some scientists say, and a handful of parasitic diseases are becoming established—yet are woefully underdiagnosed. “We’re going to start seeing more and more infectious disease outbreaks,” says Margot Kushel, a physician and scientist at the University of California, San Francisco, Center for Vulnerable Populations, which is at the Zuckerberg San Francisco General Hospital and Trauma Center.

There are many causes for these rising infectious tides, but researchers agree that a major driver is the country’s ever worsening income inequality. The disparity between America’s highest and lowest earners exceeds that of virtually every other developed country, and it is still widening. The number of households earning less than $15,000 a year grew by 37 percent between 2000 and 2016. Households earning $150,000 or more increased by exactly the same amount. In poor areas, where almost half the people live below federal poverty levels, populations doubled during this period. People on these bottom rungs of society’s ladder live in crowded, often unclean conditions, have limited health care, must work when sick, have poor nutrition, experience debilitating stress, and are more likely than others to abuse drugs and alcohol—all known infection risk factors.

What makes for large outbreaks, however, is that when illnesses start spreading through America’s urban poor, they do not stay there. Between 2000 and 2013 the country’s urban population increased by 24 million people, and crowding facilitates transmission. More city-dwelling Americans take public transportation and travel now than ever before, too, turning the nation into the equivalent of a crowded, germ-trading global market.
Changes in city infrastructure also drive up current infection risk. The huge water towers that provide buildings with air-conditioning are perfect breeding grounds for the bacterium that causes Legionnaires' disease; well-meaning attempts to conserve energy by reducing flow and water temperature in these tower systems “really amplify the conditions that allow Legionella to thrive,” says Ruth Berkelman, director of the Center for Public Health Preparedness and Research at Emory University’s Rollins School of Public Health. Many public housing and school buildings in U.S. cities are more than 100 years old and suffer from poor ventilation, which causes microbes to concentrate on surfaces and in indoor air pockets; some new buildings intentionally minimize ventilation to conserve energy. And water pipes are aging and increasingly leaking, breaking and becoming contaminated with microbes.

These disease-driving forces are social and economic rather than biological and medical, and they have been overlooked by many scientists and politicians. Few researchers have been studying how larger societal issues increase infection risk, and on the policy side, investment in disease prevention and control has been dropping. “We look more and more like the developing world, with very, very rich people and very, very poor people, and the very, very poor people are living in really abysmal situations,” Kushel says. Inattention to this divide, and not any shortfall in medical innovation, is leaving our doors wide open for infectious catastrophe.

HOW THE OTHER HALF DIES

An hour after Carpenter’s rounds, a dozen men and women had received hepatitis A vaccines in the conference room. Then a shivering middle-aged African-American woman sought the help of Carpenter and his partner that day, nurse practitioner Nicole Merenius. The woman had been having chills, a cough and congestion for several days. Carpenter administered a rapid influenza test, but it came back negative. At this point, most doctors would tell their patients to go home and rest. But for this woman, a chair in the crowded Tumaini center room was home, at least for now. She had nowhere else to go.

The nation’s homeless are among the most at risk for infectious disease for a number of reasons. They are either living on the streets, where they do not have easy access to toilets, sinks and showers, or they are staying in crowded shelters with similar problems. They are often surrounded by coughing, sneezing, sick people. Public health agencies such as the CDC tell Americans to wash their hands frequently and to stay home when ill, yet the homeless do not have the opportunity to do either. They offer profound testimony to the problem with conventional wisdom that says that infections are caused solely by germs. The truth is
The homeless, and the city in general, have been in the grip of a hepatitis A epidemic; a 10 percent increase in the illiteracy rate, they found, there was a 1918 Spanish flu swept across the globe, taking 50 million lives. Vegetables cost twice as much as unhealthy foods such as sweets. In a 2016 study published in the Proceedings of the National Academy of Sciences USA, a team of biologists and epidemiologists showed how demographics and socioeconomic status changed the risk of death in Chicago during the outbreak. Although pandemics by nature are supposed to put everyone equally in peril, the researchers found something quite different. In census tracts housing more people who were illiterate—a marker for a poverty, among other things—mortality rates were much higher than in areas with high literacy rates. With every 10 percent increase in the illiteracy rate, they found, there was a corresponding 32 percent increase in flu-triggered death. Scientists discovered, too, that the flu spread much more quickly in Chicago areas that were more crowded and had higher rates of illiteracy and unemployment compared with other city regions.

The homeless might be uniquely susceptible to infectious disease, but for similar reasons home- and apartment-dwelling individuals who live in poverty are not much better off. Financial woes incite stress, which has been shown to amplify infectious disease risk. In a 2016 study published in the Proceedings of the National Academy of Sciences USA, a team of biologists and epidemiologists showed how demographics and socioeconomic status changed the risk of death in Chicago during the outbreak. Although pandemics by nature are supposed to put everyone equally in peril, the researchers found something quite different. In census tracts housing more people who were illiterate—a marker for a poverty, among other things—mortality rates were much higher than in areas with high literacy rates. With every 10 percent increase in the illiteracy rate, they found, there was a corresponding 32 percent increase in flu-triggered death. Scientists discovered, too, that the flu spread much more quickly in Chicago areas that were more crowded and had higher rates of illiteracy and unemployment compared with other city regions.

The working poor in urban areas are also uniquely positioned to spread infectious diseases because of their job conditions. More than one million low-income Americans work as food preparers, which pays an average of $13,200 a year. Many of these workers go in even when they are ill. In a 2015 study, researchers at state health departments interviewed 426 restaurant managers around the country and reported that many of the restaurants' policies regarding working while ill violates U.S. Food and Drug Administration recommendations. Seventy percent of the managers said they had worked while sick—even with a stomach bug—because they felt obligated or worried that they would not get paid otherwise. According to a 2014 report by nonprofit Families and Work Institute, only 52 percent of employers offer paid sick leave, and among those who do, 41 percent offer it only to employees who have worked there for at least a year. "You can just imagine that if people feel they have to work or they won't get paid for that time, that you're going to have a lot of sick people at work," says Jonathan Fielding, AT THE TUMAINI CENTER, people live in chairs because the center has no beds (1). The homeless, and the city in general, have been in the grip of a hepatitis A epidemic; at the center a man gets vaccinated against the disease (2). That a person's life and circumstances strongly shape their risk. There are good data to back up this idea. One century ago the 1918 Spanish flu swept across the globe, taking 50 million lives. The opioid epidemic could also in part explain why Michigan's hepatitis C outbreak has been so deadly: 50 percent of cases were substance users, and 27 percent of them had underlying hepatitis C, which means they were hit with two liver infections at once. Substance abuse leads to risky behavior, too, including unprotected sex. A syphilis outbreak tied to drug use swept through Oklahoma City beginning in March 2017, and during the next 12 months it sickened 241 people.

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while it may have started in [the home-
we’ve finally turned a corner,” he says.

He developed sepsis, and then his body
operation because of leaking bile, a com-
then he partially rejected the new liver. This January, Kozlowicz was back in the
because a liver biopsy—his third since
to God’s hands—we’ve done everything.” He had
in July 2017, although the county health department has not been able to pinpoint the
“i was in really good shape, walking six and
a half miles a day,” Kozlowicz says. Weeks
the hospital because a liver biopsy—his third since
catching hepatitis A—had caused internal
But he was optimistic. “i think we’ve finally turned a corner,” he says.
Kozlowicz is among many middle-
and upper-class Michigan residents who have fallen ill during the epidemic. “it re-
ally is a human society issue because while it may have started in [the home-
less population], it can easily transmit to the whole of society—we’ve seen that,”
says Henry Ford Hospital’s Gordon. One large New York City outbreak of Legion-
naire’s disease was traced back to the

The same preventive shot may be less effective in poor neighborhoods than in rich ones

By Lee Riley

Health service shortfalls are often blamed for high disease rates in slums, but
service problems are not the only reason poor neighborhoods fare worse than
wealthy ones. Infectious diseases can differ at a basic biological level between rich
and poor locales, and these differences can cripple vaccines intended to fight them.

My colleagues and I have seen these effects with rheumatic heart disease in poor
parts of Brazil. This ailment has virtually disappeared from high-income
countries, where antibiotics are readily available, but it is a major cause of heart
trouble in less affluent nations, and it is often fatal. The disease is caused by
repeated throat infections from group A streptococcal, or GAS, bacteria. When
the body’s immune system attacks these microbes, some proteins in heart valve
that similar to the bacterial proteins get attacked as well.

A vaccine against GAS could thwart such infections. But the bacteria are
difficult targets. There are more than 120 different strains of these bacteria,
and a typical sore throat from these pathogens can be caused by any number of
these strains. Each has a different version of a gene that codes for M protein,
a molecule that is a key part of the bacterium’s outer membrane. To make an
experimental vaccine, researchers included M proteins from 26 common
strains to try to ensure immunity. Yet when scientists looked at non-European
and non–North American patients with GAS infections, the 26 types appeared
much less often or not at all. While these strains were frequent in high-income
countries, where the vaccine was developed, they were rarities elsewhere,
where the vaccine would be less effective.

Biological differences occur even within the same city. My research team
compared GAS strains from children in slums and in wealthy neighborhoods
in Salvador, Brazil. The collection of strains in a community is given a number
called a diversity index. The greater the number of strains with different M pro-
tein genes, the higher the index. The diversity index of GAS strains of well-to-
do children—they attended a private clinic and could afford private insurance—
was close to that reported from high-income countries, around 0.90. But the
index for slum children was higher, about 0.96. There was another distinction:
the two most common strains in high-income countries accounted for 36 per-
cent of GAS samples in wealthier Brazilian children but only for 19 percent of
samples from two slum clinics. If this experimental vaccine were to be adminis-

Vaccine Inequality

RISKY BUILDINGS

THE WAY CITIES GET BUILT SHAPES INFECTION RISKS, TOO. ON MARCH 14, 2003, A 33-YEAR-OLD MAN FROM SHENZHEN, CHINA, STARTED TO FEEL UNWELL. HE HAD A FEVER, MUSCLE ACHES AND STOMACH WOES, BUT HE WAS WELL ENOUGH TO VISIT HIS BROTHER ON THE 16TH FLOOR OF BLOCK E OF AMOY GARDENS, A HUGE HONG KONG COMPLEX CONSISTING OF 19
33-story apartment towers. While he was there, the man—identified to this day only as patient YY—had a bout of diarrhea and flushed the toilet.

Ten days later other block E residents, including patient YY’s brother and sister-in-law, started getting sick. By April 15, 99 people in block E had been diagnosed with severe acute respiratory syndrome, or SARS, a viral disease that kills between one and two of every 10 infected people. Another 222 people in other apartment blocks had the infection as well. The outbreak, which killed 42 people, ended up accounting for nearly 20 percent of all reported SARS cases in Hong Kong during its infamous 2002–2003 contagion.

Scientists spent months trying to understand why the disease hit Amoy Gardens so hard. In a paper published in April 2004 in the *New England Journal of Medicine*, researchers at the University of Hong Kong and the Chinese University of Hong Kong solved the mystery. Each column of bathrooms in the tall building, they discovered, was connected by vertical drainage pipes that branched out to each apartment’s fixtures. Every branch had a U-shaped section of pipe that fills with water to prevent rodents, insects and sewer gases from entering each flat from the system. Some U-traps, however, were just below rarely used floor drains in each bathroom, so they never filled up. Many tenants had also installed bathroom fans that created strong negative pressure, drawing air into the bathroom from those empty U-traps. One of those traps became a viral reservoir. When patient YY, who had SARS, flushed his diarrhea on March 14 (he did the same thing during a second visit to his brother on March 19), virus particles in stool droplets made it into the trap. Then the negative pressure from the fan sucked contaminated droplets into other apartments—and also out their windows and into neighboring buildings.

So when it comes to infectious disease, buildings and infrastructure matter a lot. The design of a city determines where sewage, air and water go and whether they get contaminated along the way. If rooms are poorly ventilated, the microbes people exhale or the stool droplets that permeate the air during a toilet flush get more heavily concentrated in the air over time. Yet in an otherwise laudable attempt to promote energy conservation, restricted ventilation is now a construction trend. A handful of states, including New York, Maryland, Illinois and Massachusetts, have passed laws requiring that new homes pass stringent air-tightness tests. Older buildings are being modified, too. “I’m seeing this in college buildings and other buildings, where people have tried to conserve energy and have sealed up all the leaks,” says Donald Milton, an environmental health scientist at the University of Maryland School of Public Health. In 2016 researchers at the University of Hong Kong modeled the spread of influenza in various indoor environments and concluded in a paper that “ventilation rate has a strong influence on the outbreak dynamics.” Opening a window, they noted, can reduce infection risk as much as getting vaccinated.

Water pipes are another infection source, as Amoy Gardens shows, but pipe-related problems appear badly underreported. In 2013 and 2014 the CDC reported 42 disease outbreaks associated with drinking water in the U.S., but “what makes it to the CDC outbreak database is a dramatic underestimation of true waterborne disease incidence,” says Kelly Reynolds, an environmental and occupational health scientist at the University of Arizona School of Public Health. A number of steps have to oc-

Lee Riley heads the division of infectious diseases and vaccinology at the University of California, Berkeley, School of Public Health. He is a physician trained in epidemiology and molecular biology.
cur in succession for an illness to be categorized as outbreak-related: A doctor has to see a sick individual, order a lab test that comes back positive for a reportable infection and then submit the results to the CDC. Next the CDC has to decide to conduct an investigation and determine that an outbreak is indeed taking place. A more realistic estimate of true waterborne disease burden, Reynolds says, is that 19 million to 21 million Americans are sickened by microbe-contaminated water from taps, swimming pools, hot tubs and showers every year, based on data from epidemiological and sampling studies.

Microbes build up in water for a number of reasons. In swimming pools, hot tubs and water parks, people swim while sick or while symptom-free but still contaminated, contaminating the water with infected fecal matter. (A standard dose of pool chlorine does not kill all types of germs quickly.) In addition, many drinking-water distribution pipes, particularly in older cities, have become old and leaky; estimates suggest that between 10 and 20 percent of water that leaves water utilities leaks out along the way to its destination, and “where water can leak out, contaminants can leak in,” Reynolds says. Well-meaning energy conservation efforts worsen the problem by reducing water flow, which allows microbial biofilms to build up on pipe surfaces, and by reducing the upper threshold of water temperature.

The worrying increase in Legionnaires’ disease in the U.S. highlights yet another water-related challenge. Cooling towers are increasingly popular in urban areas because they efficiently cool large buildings through water-based heat exchange. But Legionella bacteria, which naturally occur in water, thrive in such warm conditions and can sicken people when they get aerosolized and pumped out of air vents. Aerosolized shower water, fountain water and even supermarket vegetable misters can pose risks, too. Although some of the increase in Legionnaires’ diagnoses—which rose by a factor of five in the U.S. between 2000 and 2015—could be to the result of increased awareness and testing by doctors, scientists argue that the infection is likely becoming more common. “One hundred years ago we didn’t have heating ventilation and cooling systems the way we do now. Now we’ve got these bigger buildings, we’ve got the increased complexity of these plumbing systems,” Emory’s Berkelman says.

Large cities also increasingly struggle with waste management—and where there is waste, there are disease-carrying rodents. A 2007 study reported that 65 percent of rats tested in Baltimore were infected with leptospirosis, a bacterial disease that people can catch from rat urine. It can cause renal failure and lung hemorrhage. (Pets are also at increased risk, so much so that there is now a popular canine leptospirosis vaccine.) It is another potentially underestimated source of disease; some scientists worry that it is somewhat common but treated by doctors as an unidentified bacterial infection. “There’s a laundry list of pathogens that infect both humans and animals that you find in urban rats,” explains Gregory Glass, an infectious disease researcher at the University of Florida’s Emerging Pathogens Institute. “Yet if you ask how many cases of any of those have been spotted in the past 10 years, the answer is probably pretty close to zero, not because that’s the real background but because people just don’t look for it.”

Rarely diagnosed infections known as neglected tropical diseases are also likely to be more common than doctors expect. These include Chagas disease, a blood-borne parasitic infection transmitted through the bite of a kissing bug. CDC researchers estimated in a 2009 paper that more than 300,000 Americans suffer from Chagas and that 30,000 to 45,000 of them develop heart disease or heart failure every year as a direct result. The agency also estimates that 1.1 million are infected annually with trichomoniasis, a parasitic sexually transmitted disease, and that 1,000 are hospitalized yearly with neurocysticercosis, a brain tapeworm that causes epileptic seizures. “Most physicians are poorly trained in parasitic and tropical diseases. They don’t realize they’re widespread,” says Peter Hotez, dean of the National School of Tropical Medicine at the Baylor College of Medicine. “And they’re mostly diseases of people who live in poverty in the U.S.—that’s another reason they don’t get attention.”

**SOCIAL VULNERABILITY**

Scientists and public health agencies are starting to acknowledge that social factors such as poverty and living environment play an enormous role in infectious disease, yet little research directly investigates the link between the two. “It’s kind of a macro-level factor that is surely behind the risk, but it’s not specifically examined in much of the research,” says Stephen Hwang, director of the Center for Urban Health Solutions at St. Michael’s Hospital in Toronto.

One reason for this inattention is lack of money. The National Institutes of Health likes to fund research that is focused on specific diseases—on the epidemiology of hepatitis A, for instance, rather than the relation between homelessness and hepatitis A—so a broader exploration of these links “doesn’t lend itself to a sustainable research career,” Hwang says. Hotez agrees, noting that the study of the social causes of disease requires interdisciplinary investigations, work that is not generally well supported. “We don’t have a good mechanism in the U.S. to bridge disciplines,” he says. “We don’t think about teaming up with an economist, political scientist and anthropologist to solve these problems. But we’re paying the price for that.”

The Michigan hepatitis A outbreak is a perfect example of this type of tunnel vision. To curb the infection surge, the state is pouring resources into vaccine distribution, a disease-centric approach that will undoubtedly help but also overlooks the many problems, such as substance use and dangerous sick-leave policies, that made it possible for the outbreak to occur in the first place. (Many low-income Michigan residents are also refusing the vaccine, which health department officials suspect could be caused by distrust of the medical and political establishment.) And what if there is no vaccine for the next infection? In recent years pharmaceutical companies have indicated a waning interest in vaccine development; emergency vaccine efforts to combat sudden epidemics are especially expensive, risky ventures. “It’s very disruptive, and that’s not the way that we want to do business going forward,” Rip Ballou, director of the U.S. research and development center for GSK Global Vaccines, told STAT News in January. Novartis closed its vaccine division in 2014.

When the U.S. does put money into controlling an infectious disease, it also tends to stop once things improve, says Ron Valdiserri, a senior research associate at the Johns Hopkins Bloomberg School of Public Health and former deputy assistant secretary for health responsible for infectious diseases...
at the U.S. Department of Health and Human Services. There is “this notion that ‘Oh, once we have a good handle on disease, we can forget it and move on to something else,’” he says. But “with many of these infectious diseases, even when you’re successful and you can reduce new infections and you reduce incidence, they can spring back up again.” HIV is following this pattern. Although overall incidence in the U.S. has been dropping, in some poor urban areas, ethnic groups and areas of the South, the opposite is true.

Although funding amounts will ultimately be decided by Congress, the Trump administration’s budget request for the 2019 fiscal year for the CDC slashes $43 million from current programs for STD and tuberculosis prevention. (This includes HIV and viral hepatitis programs.) It cuts $704 million from public health preparedness and response, $44 million from immunization and respiratory diseases, and $60 million from emerging and zoonotic diseases. State and local health departments, which investigate and control infectious disease outbreaks on the ground as they occur, are also suffering. And their problems cannot be laid at the door of the current administration. In April 2016, before Donald Trump won the Republican presidential nomination, Gail Bolan, director of the CDC’s Division of STD Prevention, noted in a congressional briefing that 43 percent of state and local health department STD clinics had reduced their hours, and 7 percent had closed their STD clinics entirely because of funding cuts.

Back at the windowless Tumaini Center, Carpenter cares for as many people as he can. He hands out medicine, answers questions, offers snacks, asks residents how they are doing. He only works there three days a week, so addressing their many health needs is a constant challenge. To make matters worse, financial support for the Tumaini Center’s parent organization, the Neighborhood Service Organization, which provides programs and services for at-risk Detroit residents, is waning. From 2013 to 2016 the organization’s revenue from donations and grants dropped by more than 20 percent.

The U.S. has come a long way since its early battles with smallpox, cholera and polio. But modern medicine isn’t a panacea. The lives of microbes, like those of people they afflict, are shaped by their environments—and those environments are closely interwoven. As the country takes resources away from vulnerable citizens, it unwittingly enriches the strength of plagues among them.

MORE TO EXPLORE


Potential Impact of a Ventilation Intervention for Influenza in the Context of a Dense Indoor Contact Network in Hong Kong. Xiaolei Gao et al. in Science of the Total Environment, Vols. 569–570, pages 373–381; November 1, 2016.

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