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EVOLUTION, SUBSTANCE ABUSE, AND ADDICTION

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Magnitude of the Problem

Darwinian evolutionary theory made little impact on the study of human behavior for almost a century. The application of Darwinian theory to the behavior of modern humans was attempted in the 1920s–30s, but with little success. The primary weakness of this attempt, loosely referred to as "social Darwinism" was the failure to differentiate between what is and what ought to be. Darwinian theory, for all its strengths and analytical power, does not dictate a preferred course of action, one that is consistent with the general assumptions of progress, improvement, and competition. Darwinian theory simply provides an explanation for what exists at present and does not offer a master plan. As Beckstrom (1993:2) noted, evolutionary science "can act like travel agents. They cannot tell you where to go, but they can give you information about the costs and benefits of various destinations and help you get there once you finalize your decision."

If, in the last two decades, any advances have been made in the application of evolutionary theory to human behavior, science may now be able to offer some possible insights into what most agree is a pressing societal problem: substance abuse and addiction. Substance abuse is a major problem in Western society, implicated in the deaths of half a million Americans annually, with an associated monetary cost that approximates the annual budget for the Department of Defense (Horgan et al. 1993). Figure 15.1 shows the total costs for all types of substance abuse for 1990. In this chapter, I (1) briefly clarify terminology concerning use and abuse of psychoactive substances; (2) provide a brief historical perspective on drug use/abuse; (3) define the characteristics of a Darwinian trait and the extent to which substance abuse may be considered one; (4) review the available data that assess the magnitude and the costs as-

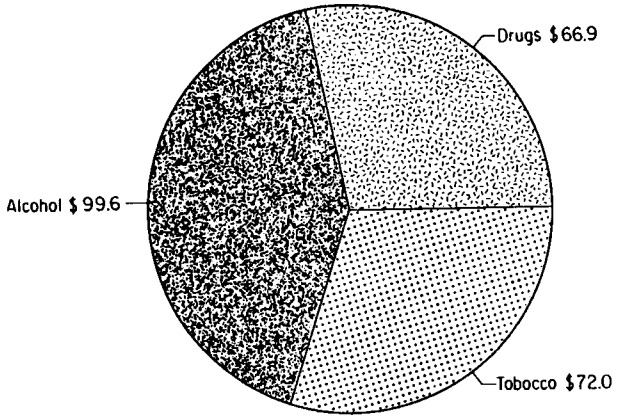

Figure 15.1. The economic costs (in $B) of substance abuse in the United States in 1990. (Redrawn from Horgan et al. 1993: 16.)

sociated with substance abuse; and (5) offer some practical observations that might assist social planners, clinicians, and others in eliminating or at least dealing with the problem from a new perspective.

Terminology

Definitional problems abound in the study of drug use/abuse. Confusion exists over what actually constitutes abuse as differentiated from use, although there seems to be slightly less confusion over what constitutes addiction (see Portenoy & Payne 1992 for a contrary opinion). According to some, if a drug is illegal, then any use is abuse, while others argue that *any use* of legal drugs is not abuse. Some confuse and often equate the use of illegal drugs with the abuse of legal ones. In this paper, I am not concerned with the legality of any particular substance, but I am concerned with a pattern of substance use that has both individual and social costs, substances that are self-administered without medical supervision, and substances that have both psychological and physical withdrawal effects.

It is clear that drug abuse and addiction are far from being a homogenous group of psychiatric problems, and it is also clear that individuals with substance abuse disorders present a heterogeneous collection of clinical symptoms (Bohn & Meyer 1994). Before discussing the evolution of something as complicated as drug addiction and abuse, it is important to present some useful definitions. The American Society of Addiction Medicine has agreed on 32 definitions of terms that are widely used in addiction medicine (Steindler 1994). The result of this adoption is a standardization of the use of terms that have often led to confusion and disagreement.[1]

In general, clinicians and substance abuse professionals distill a few characteristics of central importance in defining drug abuse. Three central features characterize drug abuse/addiction: (1) a psycho/behavioral syndrome which includes (but is not limited to) drug craving, compulsive use, self-administration not under medical supervision, and self-injurious or destructive behavior; (2) physical dependence on the chemical and increasing tolerance to its effects; and (3) physical withdrawal upon cessation of use (Doweiko 1993; Goldstein 1994; Portenoy & Payne 1992; Ray & Ksir 1990). These are general characteristics of drug abuse and are not restricted to any particular psychoactive substance.

Historical Perspective

Preagriculture

Before the rise of agriculture, access to psychoactive substances likely was limited. This is not to say that such use was not important and widespread, but rather that quantities of psychoactive substances available at any one time were limited. Psychoactive substances certainly have a long history of association with religious activities and the achievement of desired altered states of consciousness. Early uses of psychoactive drugs that ameliorated pain, such as analgesics (salicin, morphine) as well as local anesthetics (cocaine), could well have been adopted early in our evolutionary history. The sedative properties of some psychoactive substances might have been used to calm the minds of our ancestors. It may well be that some psychoactive substances initially were used for their therapeutic properties. It is well known that some plants that have hallucinogenic properties often have the side benefit of being toxic to gastrointestinal parasites. Use of hallucinogens could have originated as an effort to control parasitic infection. Diuretics such as caffeine may alter blood pressure, while members of the milkweed family (*Asclepias* spp.) contain cardiac glycosides which can have powerful therapeutic effects (Johns 1990). Plants containing natural stimulants might have provided relief from fatigue as well as elevation of mood, while others may have been used to inhibit anxious responses. Recognition of the importance of psychoactive plants was likely an important part in hominid evolution (Malcolm 1971).

Alcohol

Alcoholic beverages were possibly among the earliest widely consumed psychoactive substances. The earliest record of insobriety is found in Genesis when, after the flood, Noah is reported to have gotten drunk on wine (Gardner 1992). The earliest archaeological evidence of use of alcohol comes from about 6400 BC (Ray & Ksir 1990) and is coincident with the rise of agriculture. The oldest known preserved code of laws, that of the Babylonian king Hammurabi

written in 2225 BC, contained regulations for the conduct of business in beer and wine shops, as well as taverns (McKim 1986). Plato established strict rules of conduct for his drinking parties that required one individual, "the master of the feast" to stay sober and determine how much water was to be added to the wine (McKinlay 1951).

It is likely that there are no people on the earth that have not come into contact with alcoholic beverages in some form. Complete abstinence is not widely practiced among modern humans (except for followers of Islam and Alcoholics Anonymous), and there is considerable evidence that consumption of fermented beverages (particularly fruits) has a long history. Many foods that are regularly collected by hunters and gatherers have sufficient sugar content to ferment. In fact, one of the preferred foods of many hunters and gatherers, honey (O'Dea 1991), is perhaps the first food that was fermented and drunk (Crane 1980). Mead, a combination of honey and water, was possibly the first alcoholic beverage, appearing as early as 8000 BC (Ray & Ksir 1990). Indigenous people the world over have developed fermented drinks from a variety of sources: in Siberia red algae was used, North American Indians used maple syrup, Central American Indians produced fermented drinks from agave and cactus, South American Indians used a variety of jungle fruits, and Asians used rice (Siegel 1989).

In the ninth century the Arabs developed a distillation process to increase the alcoholic content of fermented drinks, particularly of wine (Ray & Ksir 1990). Only by distillation can the alcohol content of fermented drinks be elevated above the chemically self-limiting ceiling of approximately 12% (Goldstein 1994). England provides an interesting test case for the potency of distilled beverages and a corresponding case for the late arrival of behavioral problems associated with psychoactive substances. Until the introduction of Dutch gin into England in the early eighteenth century, alcoholism was not seen as a major problem by the government or the public at large (Goldstein 1994). Urban drunkenness, particularly among the poor, became a significant social problem with the availability of alcohol-enhanced drinks, that instead of having an alcohol content of 3–12% for beer and wines, had an alcohol content of as much as 50% or more. Distillation raised the costs for consumption of alcoholic beverages considerably because of the severity of the effects and the costs of consumption; however, it is also likely the benefits to individual consumers were also increased in terms of the quick and sustained levels of intoxication that distilled spirits can deliver. Now, of course, it is well known that public drunkenness is a part of society wherever alcohol is found (Goldstein 1994).

Tobacco

Unlike some other abused psychoactive substances, the origins of tobacco are exclusively in North and South America and are fairly recent (Jarvik & Schneider 1992). One of the first Europeans to cultivate the habit of "drinking" smoke was the Portuguese explorer Rodrego de Jerez who, upon return to Portugal

was imprisoned by the court of the Inquisition for this "devilish habit" (Ray & Ksir 1990), only to be released several years later. In spite of its rather chilly reception, smoking would eventually take hold in Europe by the mid-nineteenth century, particularly in France (McKim 1986).

Upon arrival in San Salvador, on October 12, 1492, Christopher Columbus was presented with tobacco leaves. Explorers over the next 50 years found that tobacco use was not restricted to Central America. Jacques Cartier found Indians along the St. Lawrence River smoking pipes in 1535, and in 1495 Amerigo Vespucci found natives chewing tobacco and mixing it with lime (McKim 1986). Tobacco was the most widely cultivated crop in precolonial North America. In the Northwest it was mixed with lime and chewed, while in California it was mixed with *Datura* (a powerful hallucinogen) and drunk. In Eastern North America it was smoked along with sumac (*Rhus* spp.) leaves and the inner bark (phloem) of dogwood (*Cornus* spp.) (Malcolm 1971). In Muslim countries, smoking was forbidden because it was deemed to be an intoxicant and, as such, against the teachings of the Koran. In Russia the czar punished first offenders by slitting their noses and habitual consumers were sent to Siberia or put to death (Argiolas et al. 1986). Both China and Japan instituted equally harsh punishments, but it was not long before most governments realized that there was a considerable amount of money to be made by taxing tobacco, and this tactic was used as a means of discouraging its use (McKim 1986).

Tobacco became a major addictive substance in the last century, largely through a number of technological advances. A new way of curing tobacco was developed that made smoke less irritating to air passages. Mechanization of cigarette production in the 1880s vastly increased production capacity as well as the incentive to increase the market demand. The development of the safety match should not be overlooked as having a powerful influence on the spread of cigarette smoking. New techniques of mass marketing, such as billboards, sponsorship of sporting events, clothing, and apparel have also vastly expanded the appeal of smoking (Goldstein 1994).

Unlike other psychoactive drugs, nicotine from tobacco is almost never administered in its pure form. Nicotine is highly toxic and in its pure form can have lethal consequences. Administration of nicotine in tobacco is a preferred route, for it allows precise control over the concentration of the drug ingested (McKim 1986). Tobacco cigarette smoking is the most common substance abuse disorder in the United States, affecting more than 51 million individuals, and it is the chief avoidable cause of premature deaths in the United States (Jarvik & Schneider 1992). Considerable debate has ensued over the addictive nature of nicotine, but the preponderance of evidence, both animal and human, suggests that it is addictive (Stolerman & Jarvis 1995).

Opium

Opium has a long, distinguished association with *Homo sapiens*; its history goes back more than 6000 years (Sumarians 4000 BC, Egyptians 2000 BC)

(Simon 1992). The pain-reducing properties of opium have been well known for a long time. The extent of the use of opium in early Egyptian and Greek cultures is unclear, but one of the first recorded uses was in Ebers papyrus (ca. 1500 BC), where it was described as being used to prevent the excessive crying of children. Opium was important in Greek medicine, and many believed it was a cure-all. Galen reported that opium cakes and candies were being sold on the streets as a panacea for a wide variety of ailments. Marcus Aurelius, the Roman emperor of this period, was likely addicted to opium and occasionally suffered withdrawal symptoms (Ray & Ksir 1990). In the sixteenth century, there was a marked increase in the interest in opium, largely through the efforts of Paracelsus, who developed a medication called laudanum. Although it is not clear that laudanum contained opium, Paracelsus used opium in a variety of other medications. Dr. Thomas Sydenham, father of clinical medicine, and often referred to as the English Hippocrates, developed a concoction also called laudanum that contained 2 ounces of strained opium, 1 ounce of saffron, and a dram of cinnamon and cloves dissolved in a pint of Canary wine. This is the concoction that Thomas De Quincy took that set the stage for the widespread use of opium in nineteenth century Europe (Ray & Ksir 1990). By the middle of the nineteenth century, there was widespread use of opium as treatment for a variety of clinical conditions including pain, cough, diarrhea, fever, inflammation, delirium tremens, epilepsy, melancholy, mania, asthma, poisoning, diabetes, hemorrhage, skin ulcers, snake bite, rabies, tetanus, spasmodic dysphagia, and constipation (Kramer 1980). Widespread popularity of opiates led to a most unfortunate result: the extensive use of opiates to sedate infants. Because of these practices, an untold number of children became addicted at the hands of their parents.

Morphine was isolated from opium in 1806 by Frederich Sertürner. By 1836, the clinical value of morphine was so clear that Sertürner received the French equivalent of the Nobel Prize. At about the same time in the United States, the Civil War placed a premium on the use of opiates to blunt the pain of battlefield injuries. This widespread use led to an increase in the number of addicts in this country. By the last quarter of the nineteenth century, the nature and extent of opiate dependence was being recognized (Calkins 1871), but there was little understanding of the nature of addiction. Interestingly, while opium was recognized as addictive, heroin (discovered in 1874 and marketed in 1898 by Bayer Laboratories) was thought to be relatively safe (Ray & Ksir 1990).

Use of heroin in the United States has had an interesting and complicated history, which is beyond the scope of this chapter. It is safe to say, however, that the Vietnam War, with the widespread deployment of American troops throughout Southeast Asia, and the ready availability of high-quality, inexpensive heroin did much to introduce heroin to a wide spectrum of the American populous. Today heroin use accounts for slightly more than 25% of the patients in drug treatment facilities (Horgan et al. 1993).

Coca/Cocaine

The history of the use of cocaine has been described elsewhere (Gold & Verebey 1984; Holmstedt & Fredga 1981; Kleber 1988). Briefly, cocaine is a derivative of coca, a shrub native to the eastern Andes, where it has been cultivated for thousands of years. In Bolivia and Peru, millions of Indians chew coca leaves daily. It is estimated that the average native user chews about 60 grams of coca leaves per day. Given that the alkaloid content of a coca leaf is 0.5–0.7%, and taking into account incomplete absorption, it is likely that total dosage is 200–300 mg per 24-hour period (Gawin 1991).[2] In the 1800s, coca became popular in Europe and America in the form of tonics and wines. Coca-Cola began as one of these preparations in 1896; however, by 1906 the coca extract in Coca-Cola was replaced with caffeine. By then, there were 69 imitations of Coca-Cola that contained cocaine (Grinspoon & Bakalar 1976). It was also in the mid-nineteenth century that cocaine was isolated from coca leaves. At first cocaine was used as a local anesthetic; especially for eye operations, but it quickly began to be prescribed for a variety of other ailments. This practice was quickly discontinued when it was recognized that many patients suffered ill effects from cocaine. In the early 1900s laws were passed to control the use of cocaine, but by then a huge black market had developed.

Today cocaine use has declined in the population at large, from a high of 12.2 million users in 1985 to slightly more than 6 million users in 1991; however, the number of heavy users has not significantly changed from 1985 (1985: 647,000; 1991: 625,000). This suggests that heavy use is still a real problem, particularly in urban areas where hard-core users become concentrated and drug-related crime flourishes (Horgan et al. 1993). Today the popularity of "crack" cocaine poses particularly difficult problems. Because of the relatively low price of crack compared with cocaine hydrochloride (powdered form), the rapid "high" (often within 10 seconds) makes crack particularly attractive. However, the short duration of the high (5–15 minutes) relative to that derived for intranasal administration has the net effect of increasing demand (Gold et al. 1992).

Cannabis

The earliest reference to cannabis is found in a pharmacy book written in 2737 BC by the Chinese Emperor Shen Nung, in which he referred to the psychoactive effects of the "Liberator of Sin." Social use of the plant spread to the Moslem world and North Africa by 1000 AD. The use of cannabis has a long history in the Orient and Middle East. Along with exotic spices, coffee, and tea, cannabis was introduced by early explorers to European populations. By the nineteenth century use was widespread. One of the earliest popular accounts of the use of hashish (a potent derivative of marijuana) is found in Alexander Dumas's *Count of Monte Cristo*. The psychoactive properties of cannabis were well known in Europe, and the followers of the Romantic literary tradition, as well as the Impressionist school of art, were searching for a

new intellectual experience and are known to have used hashish extensively. The early part of the twentieth century saw increasing concern about marijuana, and in 1937 the U.S. Congress passed the marijuana tax. The net effect was not to directly outlaw marijuana, but following the regulation-by-taxation theme of the Harrison Act of 1914, it taxed the grower, distributor, seller, and the consumer and made marijuana administratively impossible to deal with (Ray & Ksir 1990).

Today marijuana use continues largely unabated, in spite of concerted efforts by law enforcement agencies to reduce supply, grown both domestically and in foreign markets. Data for 1991 report 11% of eighth graders had tried marijuana and 4% said they had smoked it in the last month, while in the overall population 6.6% reported marijuana use in the last month (Horgan et al. 1993). Public opinion varies greatly concerning the dangers of marijuana. During the late 1970s, the U.S. experienced a de facto decriminalization of possession of marijuana, but today the pendulum has swung in the other direction toward a "get tough" policy for offenders (Ray & Ksir 1990). Cannabis poses a problem not only domestically, but on a worldwide basis as well. In Nigeria, estimates range from 20–50% of the male admissions to psychiatric wards are suffering from toxic psychosis from cannabis ingestion. Similar widespread use has also been reported in Uganda (Desjarlais et al. 1995).

Caffeine

Caffeine is the most popular psychoactive agent and is consumed daily by millions of people worldwide. Compared to some other psychoactive substances, caffeine is a recent arrival on the scene. The drug was first isolated in coffee in 1821, although Muslims began using coffee in religious rituals and ceremonies more than a thousand years ago. Coffee came to Europe in the seventeenth century and was soon accepted throughout the continent. Coffee drinking was so popular and widespread by this time that it was labeled an abuse by moralists of the day. In his famous *Kaffee Kantate* (1734), J. S. Bach portrays a father distressed at his daughter's addiction to coffee (Bettmann 1995).[3] Honoré de Balzac was a caffeine addict and required large quantities to work. Balzac wrote in his *Treatise of Modern Stimulants* on the effects that coffee had on him. He observed that a fortnight without coffee caused severe stomach cramps and depression (Lawton 1910). In addition to coffee, there are a variety of sources for caffeine (e.g., tea, cola, guaraná, maté, chocolate). Chocolate has only a small amount of caffeine, but has a considerable amount of theobromine, which has similar behavioral effects to caffeine.

The economics of coffee make it an important product on the worldwide market (second only to oil). The price of coffee dictates consumption patterns, and as the price of coffee goes up, consumption goes down (Ray & Ksir 1990). The per capita consumption of caffeine on a worldwide basis is approximately 70 mg/day, while in the United States this figure exceeds 200 mg/day, and some individuals report an intake of 2–5 grams/day (Greden & Walters 1992).

Caffeine intoxication is recognized by the American Psychiatric Association (American Psychiatric Association 1994) and is characterized by restlessness, nervousness, excitement, insomnia, flushed face, diuresis, and gastrointestinal problems. Coffee intoxication may be induced by consumption of as little as 200 mg of caffeine, but invariably it is induced by consumption of 1 gram or more (Syed 1976). While not posing the immediate social costs that use of other psychoactive substances carry, caffeine can have deleterious consequences for individuals, in fact, at least six deaths have been attributed to an overdose of caffeine. Lethal doses in humans have been estimated at 3–8 grams taken by mouth. Death results from convulsions and respiratory failure (McKim 1986).

Hallucinogens

Along with alcohol, hallucinogens may very well have considerable antiquity as substances widely exploited for their psychoactive properties. Hallucinogens have their origins in naturally occurring plants, and while any drug taken in sufficient quantity can induce hallucinations, hallucinogens induce hallucinations as a property of the drug directly attributable to its mode of action, as opposed to the quantity consumed. Naturally occurring hallucinogens are found in a wide array of plants. For example, they are found in the ergot fungus that infects rye and resembles lysergic acid diethylamide (LSD) in its psychoactive properties. Psilocybin is a serotoninlike substance found in several species of mushrooms (members of the genera *Psilocybe, Conocybe, Paneolis,* and *Stropharia*) native to North America. Lysergic acid is found in the seeds of the morning glory (*Turbina corymbrosa*). Dimethyltryptamine (DMT) can be found in the bark of the members of the genus *Virola*. Mescaline is the psychoactive ingredient in the peyote cactus (*Lephophora williamsii*). Myristicism is a drug that is found in the fruits of members of the genus *Myristica* and in particular *Myristica fragrans* or nutmeg. Other hallucinogens include ibotinic acid, the active ingredient in the *Amanita muscaria* mushroom (McKim 1986).

Hallucinogens are chemically related to natural neurotransmitters and, like all psychoactive drugs, act by disturbing the finely tuned neurochemistry of the brain. Hallucinogens, like other addictive drugs, are self-administered for the purpose of altering mood, emotion, and perception. Native peoples all over the world are known to use hallucinogens ceremonially, on infrequent occasions, or under the strict control of a shaman or religious leaders. This lack of widespread use may reflect a deep-seated concern about the dangerous properties of the drugs, or it may simply be due to reduced availability. Unlike other drugs mentioned here, hallucinogens have low abuse potential. They are not used in an out-of-control fashion as seen with other addictive drugs. Of all the hallucinogens, only phencyclidine might be considered addictive, because it produces dependence and an opiatelike withdrawal (Goldstein 1994).

Evolutionary Characteristics

For a trait to evolve in a population, three conditions must be present: genetic basis, variation in expression, and effect on fitness. It is a central tenet of Darwinian evolutionary theory that a trait could not evolve if it reduced the reproductive success of its carrier. In an evolutionary sense, then, one wonders how the predisposition for drug use, a seemingly maladaptive trait, could persist in the population. If drug use imposes negative fitness costs on its possessor, how could it have evolved? To determine if substance abuse is a phenomenon amenable to evolutionary analysis, let us see how well drug abuse fits the Darwinian model.

Genetic Basis

The first assumption of the evolutionary perspective is that substance abuse (or any potential Darwinian character) has at least a partial underlying genetic basis (Gianoulakis & de Waele 1994; Goodwin 1985; Harford 1992; Karp 1994; Li et al. 1994; Lumeng & Crabb 1994; Svikis et al. 1994; Vesell et al. 1971). The most compelling data supporting this position come from the studies of alcoholism, in particular "twin studies" as well as studies of children of alcoholic parents (Anthenelli & Schuckit 1992; Kendler et al. 1992; 1994). The general logic of twin studies is to assess the relative contributions of genetic and environmental factors for an illness by comparing rates of the illness in monozygotic and dizygotic twins. In the extreme, monozygotic twins should show higher rates than the dizygotic twins if the disorder is heavily genetically influenced. On the other hand, environmentally induced disorders should reveal no differences in rates of the illness between monozygotic and dizygotic twins (Anthenelli & Schuckit 1992). Kaij (1960) found the similarity or concordance rate for alcoholism among dizygotic and monozygotic twins to be vastly different, with monozygotic twins having roughly double the rate for dizygotic twins. Other studies (Vesell et al. 1971) generally support the findings of high heritability of alcoholism, although not all authors agree (Gurling et al. 1984). The preponderance of evidence supports the hypothesis of a genetic basis for alcoholism, but the results of these studies point to the complex nature of the gene–environment interaction (Anthenelli & Schuckit 1992).

Classical adoption studies have also provided researchers with a powerful methodology to study the relative contributions of genetic versus environmental factors for a variety of diseases. A number of studies have shown that offspring raised apart from an alcoholic biological parent had a significantly higher probability of developing alcoholism than those adopted children with nonalcoholic biological parents (Bohman et al. 1981; Gurling et al. 1984).

Recently, Gabel and his colleagues (Gabel et al. 1995) found a significant positive correlation between fathers who were substance abusers (SA) and increased rate of conduct disorders in their sons. The study assessed the relationship between homovanillic acid (HVA), the metabolite of dopamine (DA), an important brain neurotransmitter, and monoamine oxidase (MAO), the enzyme that facilitates the conversion of DA to HVA. Significantly higher MAO activity was found in sons of SA fathers than of non-SA fathers. These findings further support the underlying genetic predisposition toward substance abuse.

At the molecular level, there is some evidence for the genetic basis of substance abuse and, in particular, alcoholism (Bohman et al. 1981; Cotton 1979; Goodwin et al. 1973; Karp 1994; Kendler et al. 1992). One of the most compelling hypotheses about the genetic basis for substance abuse, addictive, impulsive, and compulsive disorders in general (Blum et al. 1996) concerns DA. Blum and his colleagues found at least one reward pathway in the brain that is implicated in a variety of psychiatric disorders. They suggest that an alternative form of the gene for the dopamine D_2 receptor, the A_1 allele, is implicated in altered patterns of DA release in response to challenges from a variety of sources. Although each substance of abuse affects different parts of the neural pathway (serotonin in the hypothalamus, enkephalins in the ventral tegmental area and the nucleus accumbens, and gamma-amino butyric acid (GABA) in the ventral tegmental area and the nucleus accumbens), the results are the same. Dopamine is released in the nucleus accumbens and the hippocampus.

The current model suggests that individuals predisposed toward a variety of addictive, compulsive disorders are often born with an alteration on chromosome 11 that regulates the expression of the gene that codes for the D_2 receptor gene, the A_1 allele. Individuals with the A_1 allele have approximately 30% fewer D_2 receptors than those with the alternative allele (A_2). It is well known that D_2 receptors are responsible for the inhibition of the releasing enzyme adenylate cyclase, suppression of Ca^{2+}, and activation of K^+ currents. The D_2 receptor gene controls the production of the D_2, receptors, therefore possession of the A_1 allele is implicated in a reduced number of D_2 receptors. The precise mechanism of action is unclear, but it appears that the A_1 allele reduces the expression of the D_2 allele relative to carriers of the alternative (A_2) allele. This reduced number of D_2 receptors may translate into lower levels of dopaminergic activity in those parts of the brain implicated in behavior reward. It is possible that A_1 carries may not experience normal rewards associated with dopamine activity, and this may translate into stimulus-seeking behavior or cravings. Alcohol, cocaine, marijuana, nicotine, and theobromine can all increase the level of dopamine produced and can result in a temporary reduction in craving. Blum and his colleagues suggest that affected individuals (A_1 carriers) are likely to attempt to modulate dopamine levels either by consumption of psychoactive substances or by engaging in activities that enhance dopamine production or uptake (Blum et al. 1996).

Variation in Expression

The second assumption requires that there be some phenotypic variation in the characteristic of interest. Again, relevant data come largely from studies of alcoholics, but there are possible similar patterns of variation in the use/

abuse of other drugs. Ethnic differences have been suggested to play a role in the tolerance to alcohol as well as to other drugs (Goedde et al. 1983; Yamashita et al. 1990).[4] Between 30% and 50% of the Asian population lack one of the isoenzyme forms of aldehyde dehydrogenase (ALDH), the major enzyme that degrades the first metabolite of ethanol, acetaldehyde, in the liver. After imbibing alcohol, affected individuals develop heightened blood acetaldehyde levels associated with facial flushing, tachycardia, and a burning sensation in the stomach. Not surprisingly, Asians missing this isoenzyme are less likely to drink heavily and have lower rates of alcoholism (Ewing, et al. 1974). Additionally, Jews demonstrate a low rate of alcoholism, but no underlying genetic factors have been identified. Researchers emphasize possible social practices having the net effects of controlling alcohol consumption: association of alcohol abuse with non-Jews, socialization of children into a culture of moderate drinking, adult primary relationships confined to non drinkers or moderate drinkers, and techniques to avoid excess drinking under social pressure (Glassner & Berg 1980).

On an individual basis, there is considerable difference in the tolerance to psychoactive substances, but it is unclear to what extent these are fundamental genetic differences or differences that are the result of exposure. It seems safe to say that there is modest phenotypic variation in the alcohol metabolism and presumably the metabolism of other psychoactive drugs as well, but certainly ethnic as well as individual differences play a major role in the expression of drug abuse. Figure 15.2 shows the enormous differences in alcohol consumption across a variety of different cultures, ranging from consumption of slightly more than 3 gallons of alcohol per person per year in Luxembourg to less than one-half a quart per person per year in Morocco and Trinidad. American Indians, for example, had no cultural prohibition on alcohol and when they were exposed to frontier alcohol use, were prone to "drink to get drunk." This pattern of drinking and drunkenness was liberated from social rules, and the drunken individual's behavior was tolerated (Westermeyer 1987). Binge or spree drinkers are quite common in Finland; however, these individuals remain sober most of the time and only lapse into drunkenness on occasion (McKim 1986). Aymara and Quechua Indians in the Andean Highlands engage in regular chewing of coca leaves. Periodic chewing (and smoking) of opium by "hill-tribes" in Thailand, Laos, and Burma is also well known and must be seen as a regular part of their culture. These examples are reflective of the enormous variability in drug usage patterns that are in no small part influenced by cultural constraints (Grinspoon & Bakalar 1976).

Fitness Consequences

Assessment of the effects of any particular trait on reproductive success is difficult at best because fitness should be measured in terms of the number of offspring surviving to sexual maturity and subsequently reproducing themselves. For any long-lived species then, it is difficult to accurately assess life-

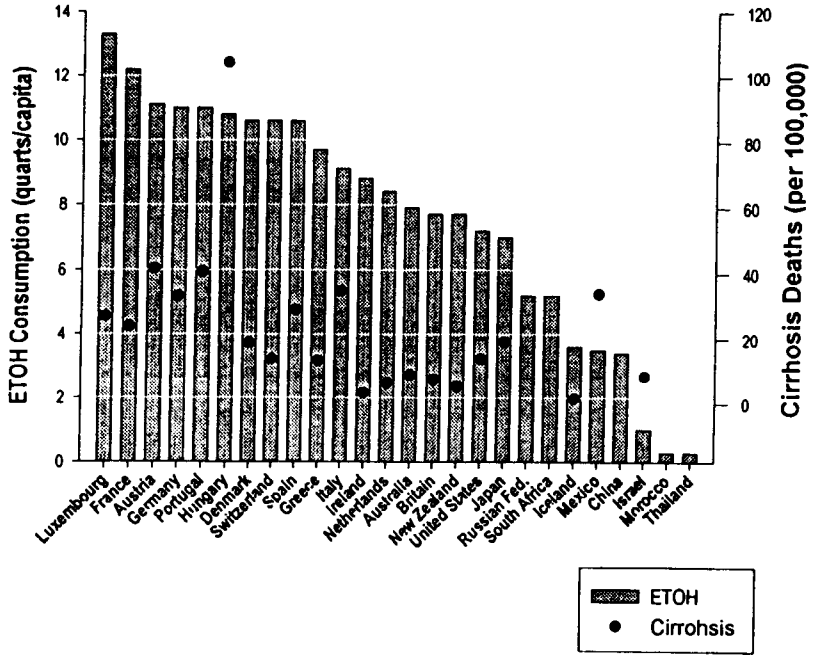

Figure 15.2. Annual alcohol (ETOH) consumption and cirrhosis deaths in selected countries in 1993. (Redrawn from Cronin 1995)

time reproductive success, the only true measure of reproductive differentials (Brown 1988; Clutton-Brock 1988; Harvey et al. 1986). The only feasible alternative, in most cases, is to measure some correlate of fitness to make any interindividual comparisons. Data to demonstrate the fitness effects of substance use and abuse are difficult to quantify, but it can be argued that there are both positive and negative consequences. The question really becomes, then, what fitness benefits might have accrued to our ancestors, such that selection for responsiveness to psychoactive substances could have been favored? These "ancestral benefits" then may have favored a trait in a historical population that still exists in modern populations, even though its function may have changed. Such benefits are now liabilities, in modern fitness terms, but our bodies still function in ways that have considerable antiquity.

Psychoactive drugs are used for a variety of reasons that ultimately may be fitness enhancing: (1) sedatives may be used for their sleep-inducing properties; (2) analgesics are used to relieve pain; (3) narcotics can be used to achieve detachment and euphoria (e.g., opioids acting in the central nervous system produce analgesia, a decreased sense of apprehension, a sense of tranquillity, increased self-esteem, and euphoria); (4) stimulants induce feelings of eupho-

ria,[5] an increased sense of energy, enhanced mental acuity, increased sensory awareness, increased self-confidence, and postponement of fatigue; (5) antidepressants are used to elevate mood and overcome depression; (6) tranquilizers inhibit anxious responses; (7) hallucinogens have been found to break down ego boundaries and heighten perception of sensory stimuli; and (8) alcohol may increase longevity, lower risk of coronary heart disease, and increase levels of high-density lipoproteins (HDL), a negative risk factor for myocardinal infarction. (See Malcolm [1971] for a complete discussion of the potential benefits of drug use.)

The initial use of psychoactive drugs can be traced to a variety of reasons ranging from the direct improvement of existing health conditions to the psychoactive properties of the substance. These initial uses, which could have been fitness-enhancing or at worst adaptively neutral, are now largely overshadowed by the fitness-reducing aspects of substance use and abuse. The key to this hypothesis is the asynchrony of selective forces on the phenotype and the corresponding effects on the genotype. Now there are significant fitness costs to many of these behaviors, but the genotypic response to these pressures is experiencing a time lag (see below).

Perhaps alcohol consumption provides the clearest picture of the costs associated with heavy substance use. Alcohol has been widely found to have a disinhibitory effect on consumers and as such is implicated in the expression of aggressive behavior (Giancola & Zeichner 1995; Laplace et al. 1994; Pihl & Peterson 1995). Although not indicative of the costs in a historical or evolutionary perspective, nearly half of the convicted felons in the United States are alcoholic (Golding 1993; Murdoch et al. 1990) and about half of all police activities in large cities are associated with alcohol-related offenses (Goodwin 1992). Overall, the death rate for alcoholism is approximately 3% of total deaths in the United States (Winick 1992). More than 19,500 deaths were directly attributable to alcohol numbered, while alcohol was indirectly implicated in an additional 88,900 fatalities in 1989 (Horgan et al. 1993). Other adverse consequences of alcohol use include an intimate association with suicide and homicide. In at least 50% of the homicides worldwide, the slayer, the victim, or both had measurable blood alcohol levels. Alcohol is involved in about 75% of the suicides and as many 86% of murderers (Lester 1992; 1995; Rich et al. 1986) in the United States. Cross cultural data have confirmed the association between alcohol and violence. In Papua New Guinea, beer consumption doubled every 4–5 years during the period 1962–1980; this increase was accompanied by a 400% increase in traffic fatalities as well as increases in death and serious injury from blunt trauma, knife, and bullet wounds (Desjarlais et al. 1995). Estimates of the prevalence of alcohol use vary, but it is estimated that 140 million Americans consume alcohol. Of these, 18 million are reported to be alcoholics or alcohol abusers (Nadelmann 1989). The total cost of alcohol abuse in the United States alone is estimated at near $100 billion annually (Horgan et al. 1993) (see Figure 15.3).

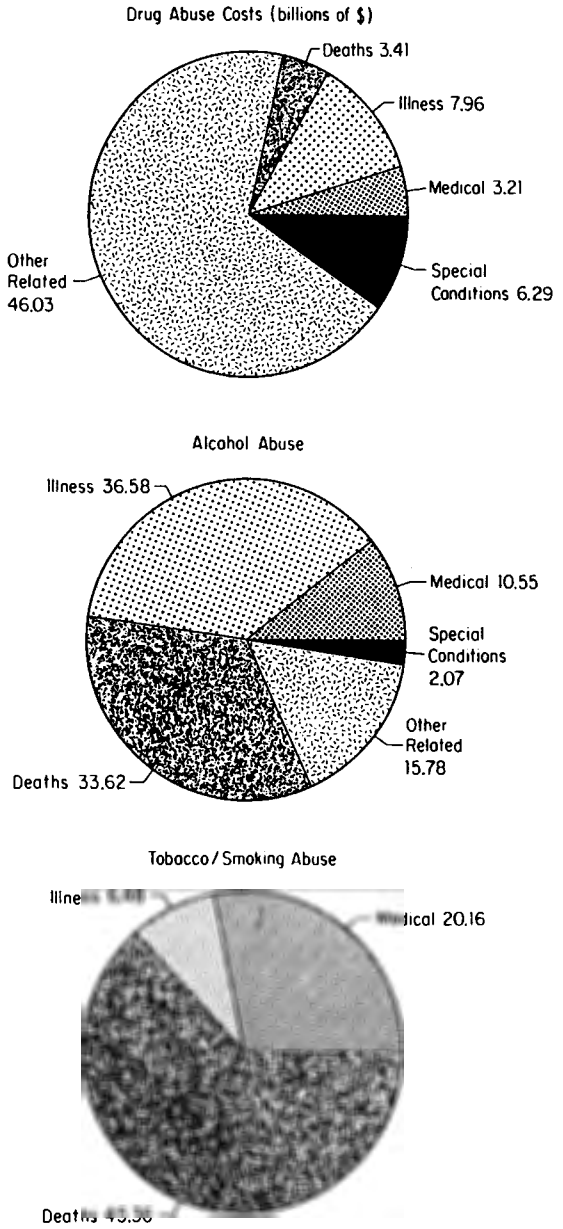

Figure 15.3. Substance abuse costs, by category, in the United States in 1990. (Redrawn from Horgan et al. 1993: 16.)

Perhaps the most unfortunate cost of alcohol consumption is seen in infants of alcoholic mothers. In the overall U.S. population, fetal alcohol syndrome (FAS) affects about 0.4–2.9 births per 1000, but for mothers who are alcoholic the rate climbs to an astonishing 23–29 births per 1000. If all alcohol-related birth defects are counted, the prevalence rate may be as high as several hundred per 1000. It may be that maternal alcohol abuse is the most frequent known environmental cause of mental retardation in the Western world (Ray & Ksir 1990).

In Russia, current estimates suggest that 20–25% of the adult population is alcoholic. There is one female alcoholic to every five male alcoholics. The prevalence varies significantly by occupation; 10% of the workers in the nuclear power industry suffer from alcoholism and 42% of those in the woodworking industry are afflicted. It is further estimated that only one in seven alcoholics seeks professional help in Russia (Matilainen et al. 1994). Alcoholism has reached record proportions among aboriginal groups on Taiwan. Lifetime prevalence rates range from 68.1% to 72.3%. These rates are approximately twice what we see in two other well-studied populations, Peruvian Indians living in Lima (34.8%) (Yamamoto et al. 1993), and Mexican-Americans living in Los Angeles (31.3%) (Karno et al. 1987).

Nicotine addiction provides another useful example. Estimates of the extent of nicotine addiction are difficult to obtain, but it is estimated that 26% of Americans (46 million) smoke, and of these 80% would like to stop and try to do so each year. Only 2–3% of those who try to stop succeed. The economic costs of smoking/tobacco use in 1990 was estimated at $72 billion (Horgan et al. 1993), which is slightly more than the 1990 fiscal budget for the education department ($23.1 billion), the energy department ($12 billion), the justice department ($6.5 billion), and the transportation department ($28.6 billion) combined (see figure 15.3).

Data for other psychoactive drugs are not as detailed, but they also paint a similar picture of the costs of excess consumption (See figure 15.3). For example, even though heroin was introduced into Pakistan only 20 years ago, that country has the highest per capita use of heroin in the world (2.03% of the urban population and 1.36% of the rural population, totaling 1.5 million heroin addicts). Data are not available on the worldwide costs of substance abuse, but total estimated costs of substance abuse in the United States in 1990 exceed $235 billion. This is approximately 23% of the total receipts for the government in 1990. This is an astonishing figure that suggests the benefits of substance abuse must be extraordinary to outweigh the heavy costs. Continuation of the use of substances with such substantial negative effects poses an interesting dilemma. Negative outcomes may occur relatively infrequently, and the possibility of their occurrence may be overwhelmed by the likelihood of pleasurable consequences (Critchlow 1986), but when negative outcomes do occur, the costs are high. The only psychoactive drug that increases negative health outcomes for virtually all users (addicts or not) and for those in the vicinity of the use is tobacco. In these cases, however, the harm is caused by the toxic content of the smoke, not the behavior of the user.

Alternative Hypotheses

In Western society, drug abuse is seen both as a societal problem but more importantly, in many cases, as an individual problem that is to be overcome. Historically, drug abuse has been characterized as a moral or constitutional weakness directly reflecting the character of the individual (Thomason 1938).[6] If, rather than viewing substance abuse as a character flaw or fundamental constitutional weakness, it is viewed as the outcome of complex interactions between biological and social factors, then a new perspective may be developed that is helpful in identifying aspects of the problem that are amenable to clinical intervention. If we consider substance abuse as having underlying biological components, then we are forced to ask how such seemingly maladaptive traits could have evolved. It seems that there are at least several possible hypotheses to explain both the evolution, as well as the maintenance, of this most enigmatic behavior in modern populations. Historically, hypotheses focus on the proximate or neurodevelopmental mechanisms that may contribute to addiction, but rarely have researchers considered the evolutionary basis for the psychiatric phenomenon.[7] I attempt to outline some of the more conspicuous hypotheses below.

Constitutional Weakness—"Pharmacologic Calvinism"

The idea that excessive use of alcohol, or any psychoactive substances for that matter, is a moral problem has a long history in Western thought. King James I (1604) wrote that drunkenness was the root of all sins. Many historical events have signaled the widely held notion that intemperance was among the chief evils of society. Certainly, Prohibition in the United States was an excellent example of the belief in the evil powers of alcohol and drug use. Prohibition was not just a matter of political convention or health concerns, but a complex interplay of these factors with a middle-class, rural, Protestant, evangelical concern that life was being undermined by ethnic groups with different religions, a lower standard of living, and lower standards of morality (Ray & Ksir 1990).

In more recent times, one of the most articulate spokesmen of this opinion was the first "drug czar," the Director of the National Drug Control Policy Center, Dr. William Bennett, who said, "We identify the chief and seminal wrong here as drug use. Drug use, we say is wrong" (Weinraub, 1988:A1). In an editorial the *Wall Street Journal* further echoed these sentiments, "We agree with Drug Czar William Bennett that this [substance abuse] is in no small part a moral question. This nation is suffering a drug epidemic today because of the loosening of societal control in general, and in particular because of the glorification of drugs during the 1960s" (Wall Street Journal 1989:A6).

Those who hold this position see the problem as primarily one of morality and also tend to see enforcement as the key. Bennett also noted "those who use, sell and traffic drugs must be confronted, and must suffer consequences . . . We must build more prisons. There must be more jails. We must have more

judges to hear drug cases and more prosecutors to bring them to trial" (Massing 1990:32). The focus of this position is not on the drugs themselves, the behavior of those who consume drugs, the negative health consequences for those that use drugs, or their families, friends, and communities. The focus is on morality.

An evolutionary perspective on drug abuse is distinctly at odds with this hypothesis largely because evolutionary theory makes no assumptions about absolute moral questions. Substance abuse *is* and apparently *has been* for a significant part of human history. Whether it is morally acceptable is *not* the question. It is social problem of growing magnitude and seriousness and in order to control it, we must understand it as completely as possible.

Handicap Hypothesis

Jared Diamond in *The Third Chimpanzee* (1992) applies one of the classic theories of sexual selection to the use and abuse of drugs. Following Zahavi's (1975, 1977, 1991) handicap hypothesis, Diamond (1992) suggests that humans use drugs and engage in other risky behaviors (bungee jumping, hang gliding, sky diving, etc.), particularly in adolescence and early adulthood, as a means of gaining status. Consistent with this view of sexual selection is the observation that males are more likely to engage in this "risk-taking" behavior." The messages of our old and new displays nevertheless remain the same: I'm strong and superior. "Even though I take drugs only once or twice, I must be strong enough to get past the burning, choking sensation of my first puff on a cigarette, or to get past the misery of my first hangover. To do so chronically and remain alive and healthy, I must be superior (so I imagine)" (Diamond 1992: 199).

The handicap hypothesis was developed by Zahavi to explain the existence and maintenance of expensive anatomical accoutrements and behaviors primarily used by males in attracting mates." It is well documented that males engage in drug-taking behavior significantly more than females (Horgan et al. 1993), and by doing so are possibly advertising their fitness to females. While Diamond's argument might make sense for substance abuse by males, it does little to inform questions about females' abuse of psychoactive substances. In general, because of differential parental investment in offspring, males are the sex that must demonstrate their superiority over others of the same sex to secure successful matings. Females, on the other hand, experience disproportionately high costs of producing offspring and are not selected to take risks to demonstrate their fitness.

Cheating and Reproductive Advantage

The cheating and reproductive advantage hypothesis suggests an evolutionary link between alcoholism and antisocial personality disorder (ASPD) (Kofoed 1988; MacMillan & Kofoed 1984). These two disorders co-occur frequently, and there are several hypotheses about their relationship. Seventy percent of

men with ASPD have secondary alcohol problems (Anthenelli & Schuckit 1992). The important point is that the disorders are distinct, but they are often found together in the same individual because of selective pressures. Evidence suggests that individuals with both disorders are more successful in sequestering mating opportunities than those with only one. Cheating and deception are viewed as reproductive tactics by many evolutionary biologists (Bond & Robinson 1988; Byrne & Whiten 1992; Kutchinsky 1987; Smith 1987; Welles 1981; Whiten & Byrne 1988). To maximize fitness, individuals will engage in a variety of behaviors that enhance their fitness at the expense of a competitor.

Cheating as a reproductive tactic typically involves males seeking sexual relationships in indiscriminate ways so that they do not invest in the offspring of any particular female, but at the same time they try to inseminate as many females as possible. Females are fooled into believing that these "cheater" males will provide parental investment and consequently allow themselves to be fertilized by these males. According to this hypothesis, individuals with ASPD find themselves in a society that condones the use of alcohol as well as its enhancing effects on the likelihood of sexual activity (albeit at relatively low doses). The confluence of the two disorders provides reproductive opportunities for affected individuals who otherwise might have been precluded from mating. Individuals with the tendency toward positive experiences with alcohol are especially prone to abuse, and when coupled with a predisposition toward ASPD, individuals who carry a genetic predisposition for both conditions are likely to be produced. Phenotypes with both conditions will enjoy enhanced fitness relative to individuals with only one of these conditions. Males, in particular, are predicted to be good at deceiving females, often using alcohol to set the stage for mating attempts. Females must be duped into unreciprocated investment. It is likely that many of these attempts result in failure, but in evolutionary terms, according to this hypothesis, cheating males were sufficiently successful to pass along the genetic characteristic.

Evolutionary By-product

It is possible that the tendency to abuse psychoactive substances is an evolutionary by-product of selection for some other set of characteristics. *Pleitropy* is a phenomenon that occurs when a gene has more than one, apparently independent, phenotypic effect (Hartl 1994). In this case, the propensity to differential responsiveness to psychotropic substances may simply result because of selective pressures for some other character, and one of the multiple effects of selection is the increase in frequency of addictive behaviors. For example, the gene for a highly selected character, enhanced spatial perception, for example, as well as differential psychoactive drug susceptibility, may be pleiotropic effects of the same gene. In that case, the evolutionary costs of such a deleterious trait are balanced against the benefits of the positively selected characteristic. Hence, the maladaptive trait persists in the population in the face of negative consequences because of the compensatory benefits of the selected phenotypic characteristic.

Pleitropy is well known in the evolutionary literature and has been used to explain the evolution of seemingly maladaptive traits in a variety of species. It is possible that the trait in question is subject to directional selection for increase in the mean, but it is genetically negatively correlated with another trait. Individuals who take risks in a variety of types of behaviors may be favored early in life, but those who engage in risky behavior have a shortened life expectancy. This would give the appearance of a positively selected character which has the net effect of lowering fitness (Futuyma 1986).

Phenotypic/Genotypic Asynchrony

If the use and, ultimately, the abuse of psychoactive substances is the outcome of Darwinian evolutionary processes, then what could have been the possible fitness benefits of this behavior? Is it possible that we can treat substance abuse and addiction as an evolved trait like a predisposition to cancer, heart disease, osteoporosis or MS? Do humans, as some have suggested, have a predisposition toward the use of psychoactive substances? Is it possible that like hunger, thirst, and sex, intoxication may be a basic part of the human condition (Siegel 1989)? If this view is correct, then it seems important to analyze the human use of psychoactive substances, not as something dictated entirely by cultural convention and opportunity, but also as a reflection of our evolutionary history.

It is relatively easy to imagine the fitness-enhancing aspects of the use of psychotropic substances in our evolutionary past. From the reduction of stress, improvement in performance, increased sociability, or the simple reinforcing properties of altering psychic state, the use of psychotropic substances could have directly affected fitness. Use of psychotropic substances could have been favored by those who were particularly sensitive to the effects, and in responding they might accrue slight fitness advantages over those less susceptible. This tendency could have been held in check during the course of the evolution of modern humans by the lack of large quantities of highly potent psychoactive drugs. Those substances that were available were all naturally occurring and lacked the concentration of highly refined or synthetically produced substances today. Hence, individual behavior would likely rarely have gotten out of control and become pathological. Today, however, the ready availability and high concentration of psychoactive substances can produce dire consequences.

If as some biological anthropologists have argued (Eaton & Konner 1985; Eaton et al. 1988, 1994), modern humans are basically equipped with the anatomy and physiology of our Paleolithic ancestors, then it may well be that a significant part of the behavior of modern humans directly reflects the evolved behavior of our ancestors. In that case, an evolutionary perspective allows the development of hypotheses about the adaptive significance of a behavior that evolved in a very different ecological setting than the one found in today. Differential responsiveness to psychotropic drugs may have had positive consequences in the past, while imposing heavy costs in the modern setting.

Dopamine Hypothesis

The focus of this chapter is on the evolutionary mechanisms that might have favored drug use in our not-so-distant past. The proximate mechanisms that might be implicated in the maintenance of a genetic predisposition to abuse psychotropic substances are not well developed, but one of the most promising hypotheses concerns the production of a powerful neurotransmitter, dopamine. This hypothesis was originally formulated as a proximate mechanism to explain alcoholism (Blum & Payne, 1991), but has been expanded to include a variety of other obsessive, compulsive disorders (Blum, Cull, Braverman, & Comings, 1996). (See brief discussion above.)

Individuals who exhibit addictive behavior suffer from a neurochemical deficit. Under normal resting conditions a person with this genetic predisposition to drug use cannot achieve feelings of well-being routinely experienced by normal people because not enough dopamine is being released and not enough can bind to the dopamine D_2 receptors in the reward part of the brain. Because of this deficiency to dopamine, a super-sensitivity develops in the nucleus accumbens, the major reward site of the brain. Anything that brings about a release of dopamine, even small amounts of alcohol or other psychotropic drugs, can lead to powerful feelings of well-being. The alcohol- or drug-prone individual experiences a sense of pleasure and marked well-being with the first ingestion of psychoactive substances. The individual is resistant to the adverse effects (loss of motor control, dizziness, and nausea) of the substances. Drugs and/or alcohol temporarily set off the release of dopamine sufficient to mediate the naturally low levels and induce a powerful feeling of well-being. This is precisely the reason that alcoholics consistently report a strong desire to maintain that feeling of euphoria produced by the first few drinks. If, however, the alcohol-prone individual continues to consume alcohol, a number of neurochemical changes can occur, which may include, but are not limited to, a decrease in the number of dopamine recptors (D_2), an increase in the breakdown of dopamine, a decrease of dopamine released at the nucleus accumbens, and a general lowering of neurotransmitter activation at reward sites in the brain. A person drinks more, but the effects decrease and the damage to reward centers increases, intensifying the craving for more alcohol. Again, this explains why the alcoholic will continue to consume alcohol in an effort to regain the euphoria associated with the first few drinks, but is destined, because of the nature of the feedback system, to never be able to experience it. Although the precise neurochemical pathways have not been worked out in detail for other substances, it is likely that similar phenomena are an intrinsic part of most substance abuse (Blum 1989; Blum & Noble 1994; Blum & Payne 1991; Blum et al. 1996; Noble et al. 1994).

Individuals with differential drug responsiveness likely have existed in human populations for many generations, but it is only recently that substances that short-circuit the adapted neural pathways have become widely available and in highly concentrated forms. The rise of agriculture and the domestication of potentially psychoactive plants is a recent phenomenon in human ev-

olution (perhaps no more than 400 or so generations), but the consequences of the human desire to seek pleasure and avoid pain are extraordinarily deeply rooted in our evolutionary past.

Evolution and Addiction: Application of the Theory

If drug abuse/addiction is amenable to an evolutionary analysis, one of the first questions that must be considered is why do humans use psychoactive substances in the first place? It is important to remember that much health damage results from behavior directed toward increasing pleasure or avoiding pain. People use tobacco, alcohol, etc., because these substances make them feel good, get them high, and/or help them relax and forget their problems. In an evolutionary perspective, it makes perfect sense that our neural circuitry, especially in the brain, has undergone strong selective pressure and extensive modification toward this end. Behaviors that increase pleasure or avoid pain have been associated with activities that are essential for survival and reproduction (food, sex, human attachment, rest, athletic proficiency, etc.) and have been the object of intense evolutionary pressure. The fact that individuals find these activities pleasurable generally enhances our Darwinian fitness. If individuals did not find these survival activities pleasurable, then our species would have become extinct a long time ago.

However, as every parent knows, not everything that feels good may be good for us. Natural selection will favor individuals over time who avoid certain potentially harmful substances or experiences. To the extent that avoidance has some genetic basis, natural selection will act on it, but there are a variety of reasons it typically takes a number of generations for selection to act. When a substance or experience is first introduced to the population, the situation is very different—there will be no evolved safeguards to limit an individual's exposure—and this is when selection is most intense. This introduction can occur in two ways: individuals can be exposed to a *completely new* substance or opportunity (e.g., alcohol and tobacco), or individuals can be exposed to *more* of a substance or opportunity that has in the past promoted survival and reproduction, but exposure was in considerably more limited quantities (e.g., salt and fat). This argument may be summarized as the Pleistocene hunter-gatherer model.[10]

These recent changes in the type, as well as extent, of exposure to substances that are harmful to us are a price of the affluence of Western society. These recent changes (e.g., introduction of highly concentrated and readily available psychoactive substances) stimulate old, deeply rooted survival-trait–based neural circuitry that urges us to consume these substances in large quantities in order to reap the pleasure bonanza. The body does not know that the high induced by the consumption of alcohol, smoking of crack cocaine, or injection of heroin is disconnected from the evolutionary antecedent survival behaviors. The body operates with a fairly simple algorithm—maximize pleasure and minimize pain and discomfort. If ingestion of exogenous substances produces emotional responses that mimic those generated from the performance of evolutionarily adaptive behaviors, then it is wholly reasonable to expect that people will continue to engage in those behaviors, ones that generate the maximum pleasure with the minimum effort. Simply put, people want to experience pleasure and avoid pain, drugs short circuit the evolved mechanisms and directly produce pleasure or ameliorate pain and discomfort. Today we no longer see a "goodness of fit" between the performance of fitness-enhancing behaviors and the resulting feelings of pleasure and satisfaction. In a real sense we find ourselves in a rapidly diminishing downward spiral.

Earlier in this chapter I briefly alluded to the magnitude of the problem of substance abuse. Accurate estimates of the numbers of abusers are as elusive as a definition of the phenomenon, but data indicate that overall prevalence rate for substance abuse in public and private psychiatric populations is about one in two. The prevalency rates for addictive disorders varies in the clinical populations: 30% in depressive disorders, 50% in bipolar disorders, 50% in schizophrenic disorders, 80% in antisocial personality disorders, 30% in anxiety disorders, and 25% in phobic disorders (Miller 1994). It is estimated that as much as 20% of the population may be affected.

Figure 15.4 shows the lifetime prevalence of the top 10 major psychiatric disorders in the general population. Combining estimates for alcohol and substance abuse, the prevalence is 19.6%. If these estimates are correct, then one out of five people in the United States have a substance abuse problem (Miller 1994). These data strongly suggest that current approaches to substance abuse treatment have been only marginally effective at best, and if we are going to deal with this most pressing problem we are going to have to develop new and novel ways of looking at the problem.

If the evolutionary model I have suggested is correct, then what can we say to the larger question of substance abuse? Several suggestions come to mind: First, an evolutionary perspective removes substance abuse from the realm of moral judgment. Like cancer, heart disease, and muscular dystrophy, substance abuse arises from biological origins rooted deeply in human evolutionary history. This awareness should begin to undermine the widespread notion that individuals plagued by the disease of addiction lack willpower or lack self-restraint. To discriminate against substance abuse makes about as much sense as discrimination against males with pattern baldness. Second, and closely related to the first, is the establishment of realistic goals for use of psychoactive drugs. Given our evolutionary history, it is unreasonable and unrealistic to aspire to a "zero-intake" society. It is reasonable, however, to expect that we may achieve, not a drug-free society, but one with substantially less drug abuse. By understanding the mechanism of action and the potential basis for widespread use in the face of empirical data about the costs of substance abuse, we may be able to make rational decisions about treatment as well as prevention. Third, serious efforts should be made to reduce the ease of acquisition of legal drugs. This could be accomplished through restriction

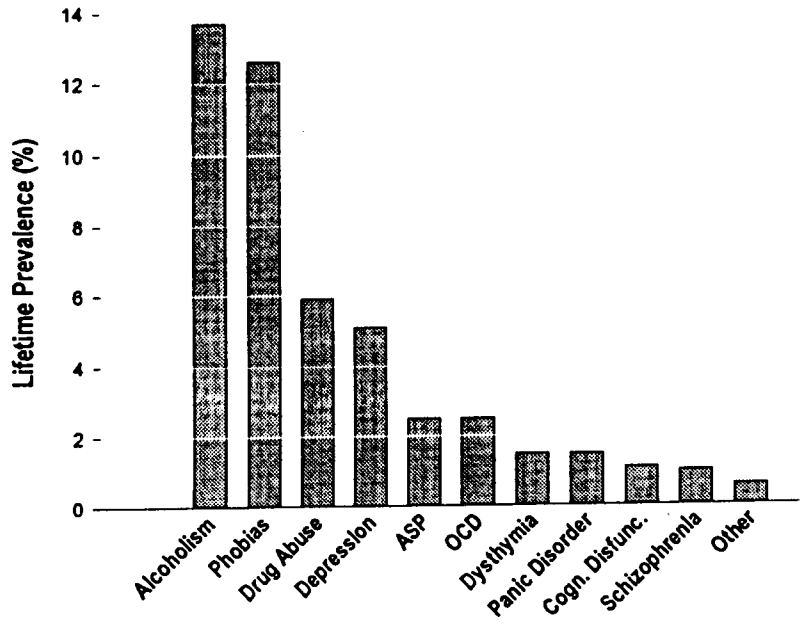

Figure 15.4. Lifetime prevalence of the top 10 psychiatric disorders in the United States (Miller 1994).

of the sale of all alcoholic beverages as well as all tobacco products to state-owned liquor stores. This would make acquisition costs higher, as well as place the sale under tighter control, thus reducing the probability of selling to minors. Fourth, the evolutionary perspective should help focus attention on education and treatment, rather than on punishment and retribution. See Goldstein (1994) for a discussion of several of these ideas. These suggested remedies would, no doubt, be expensive, but relative to the $240 billion per year costs of substance abuse, the current expenditures on treatment costs alone by the federal government, $8.2 billion in 1990 (Rouse 1995), seems insignificant (Johnston 1988). In fact, alcohol and tobacco industries spend slightly more than half the total government expenditure on treatment on advertising annually.[11]

Finally, the dopamine model (Blum et al. 1996) suggests that a profitable area for continued research will be in the development of substances that enhance the production of dopamine or other neurotransmitters without the addictive side effects. Addicts could then maintain a normal neurochemical balance without resorting to destructive behavior. Individuals with a wide array of addictive, impulsive, and compulsive disorders might be able to find relief from potentially lethal situations through modulation of neurotransmitters. Although this is merely speculation at this point, given the advances in other areas of evolutionary biology and neuroscience, it seems to me that continued application of the evolutionary perspective is both critical and is likely to prove very fruitful.

Acknowledgments

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Notes

1. Steindler (1994: 2.1–2.2) notes that

> Abuse is the harmful use of a specific psychoactive substance; addiction is a disease process characterized by the continued use of a specific psychoactive substance; addiction is a disease process characterized by the continued use of a specific psychoactive substance despite physical, psychological or social harm; and dependence is either physical dependence, a physiological state of adaptation to a specific psychoactive substance characterized by a withdrawal syndrome during abstinence, which may be relieved in total or in part by the readministration of the substance, psychological dependence, subjective sense of need for a specific psychoactive substance, either for its positive effects or to avoid the negative effects associated with its abstinence or as a category of psychoactive substance use disorder.

2. Compare this to what is considered a large dose in modern populations of 800 mg in single dose (Grinspoon & Bakalar 1976). Information on lethal doses of cocaine are somewhat problematic, but in one experiment (Pickett 1970) notes that the equivalent of an injection of 2 grams in a 150-lb man proved lethal in 50% of the experimental subjects.

3. Bach's affinity for coffee is not definitely known; however, an inventory of his estate revealed that the kitchen was equipped with numerous coffee pots. A particularly impressive one was assessed for 18 thalers (approximately $2000 today) (Bettmann 1995).

4. See Ewing et al. (1974) for a contrary opinion.

5. Athletes have known for a long time that amphetamines enhance performance, but the effect is generally recognized as small. Historically, it has taken about 7 years to decrease the record time for the one mile run by 1%. Imagine the impact a 1% decrease in time could make, particularly at the highest levels of competition (Laties & Weiss 1981; Smith & Beecher 1959). A survey of Olympic records for 68 of the 250 Olympic events revealed that an improvement of 1% in performance would have changed the winner in approximately three-quarters of these events (50/68). In fact, Gemini-Titan astronaut Gordon Cooper was ordered

to take amphetamines before assuming manual control of the reentry of the space vehicle (Ray & Ksir 1990).

6. Many clinicians argue that there is little convincing evidence to suggest that substance abuse is anything more than an environmentally induced social pathology with no underlying basis in biology.

7. Although see Nesse (1992, 1994) for the first application of evolutionary theory to psychiatric disorders in general and substance abuse in particular.

8. Sexual selection (Trivers 1972, 1985) predicts that because males generally have lower investment in offspring, they are predisposed to demonstrate their superiority as mates by engaging in flamboyant, extravagant displays. Females, on the other hand, due to their greater degree of intrinsic investment in offspring, are favored to be choosy in their selection of mates.

9. Zahavi developed these ideas to counter the argument for "runaway selection" advanced by Fisher (1930).

10. The Pleistocene hunter-gatherer model has been invoked in anthropology to explain a variety of conditions found in modern humans, ranging from our aggressive tendencies, to configuration of sex organs, to social organization, to bipedalism.

11. The tobacco industry is reported to spend $4 billion annually on advertising in the United States (Bristow 1994); the alcohol industry invests $700 million in advertising (Arnesen 1995).

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