Sexually Transmitted Diseases, December 2006, Vol. 33, No. 12, p.698–702
DOI: 10.1097/01.olq.0000250476.76031.e8

Social and Behavioral Determinants of Sexually Transmitted Disease: Scientific and Technologic Advances, Demography, and the Global Political Economy

SEVGI O. ARAL, PHD

From the Department of Science, Division of STD Prevention, Centers for Disease Control and Prevention, Atlanta, Georgia

THIS IS A GREAT HONOR and a very humbling experience. I am very grateful to all who made this moment possible—to the American STD Association, to the selection committee, to those who nominated me, and to the whole field of sexually transmitted disease (STD) epidemiology and prevention. I am particularly grateful to King Holmes, Ward Cates, and Russ Alexander for their heavy duty mentoring throughout, but especially during the early years. Mentoring me was slightly different than mentoring a Harvard- or Yale-trained MD. I had to be taught how to speak and write in English; I had to be taught STD and epidemiology. I had to be introduced to the American culture, the medical culture, the Centers for Disease Control and Prevention culture, the public health culture; and I badly needed self-confidence enhancing behavioral interventions. My mentors have been extremely patient with me. However, it takes a village to make a career (Fig. 1). I have learned and received support from so many individuals; some directly, some indirectly; some thought they were learning from me while they taught me. Some thought they were receiving support from me while they supported me. I cherish each of them and am very grateful to all.

Often the Parran Lecture is a description of the recipients' series of accomplishments. Alternatively, it can be the description of one recent achievement. When I look back on my career up to this point, what I find remarkable is not what I have done, but rather, what I have observed happen in the field; so much has changed since 1978. Robert Frost had said, "How many things have to happen to you before something occurs to you?" In what follows, I describe some thoughts that occur to me based on developments in science, technology, demography, and the global political economy at this point in time.

One relevant scientific contribution is the argument by Duncan Watts and colleagues that population structure is relevant to the spread of infectious disease, and traditional mathematical models have understated the role of nonhomogeneous mixing in populations with geographic and social structure.[1] The recently proposed geographic and network models do incorporate various aspects of interaction structure among individuals, but these complex models have low tractability and general conclusions are notoriously difficult to draw from them. Watts and colleagues introduce a class of metapopulation models. They assume homogeneous mixing within local contexts. They also assume local contexts are embedded in a nested hierarchy of successively larger domains. The movement of individuals between contexts is modeled through transport parameters and disease spreads stochastically. This model successfully reproduces aspects of real epidemics, including extreme size variation and temporal heterogeneity, which have been difficult to reproduce with the traditional compartment models as well as recent network models. The results of this work also suggest that when epidemics do occur, the basic reproduction number R_o may bear little relation to their final size. The large variations in epidemic size and the resurgence behavior derive not from average statistics like R_o, but from rare, stochastic events in which the epidemic escapes from currently infected contexts into newly susceptible populations. Individuals introduce disease to previously uninfected groups. Thus, stochasticity is important not only at the outset of an epidemic, but throughout its entire progress.

As suggested earlier by Bailey,[2] global epidemics should be considered as many smaller epidemics occurring in different subpopulations; most transmission occurs at the subpopulation level; broader spread depends on mixing between subpopulations. The final size and duration of the epidemic are highly sensitive to the structure of the population through which it spreads even when the basic reproductive number is held constant. Conversely, similar distributions of epidemic size can correspond to very different values of R_o. The details of this multiscale hierarchical metapopulation model will probably evolve and improve in the future. The model is not yet developed for sexually transmitted infections.

This model has important implications for future directions in the social and behavioral aspects of STD epidemiology and prevention. Some of the questions we may pursue in the future include: What are the sexually relevant meta population structures? What is the structure of sexual segregation? What parameters define the boundaries around sexual links or subpopulations within which there is random sexual mixing? How do sexually

The author thanks Patricia Jackson for her outstanding support in the preparation of this article.

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the Center for Disease Control and Prevention.

Correspondence: Sevgi O. Aral, PhD, Division of Sexually Transmitted Disease, National Centers for HIV, STD and TB Prevention, Centers for Disease Control and Prevention, 1600 Clifton Road, Mailstop E02, Atlanta, GA 30333. E-mail: SAral@cdc.gov.

Received for publication September 13, 2006, and accepted October 10, 2006.

Fig. 1. It Takes a Village.

relevant metapopulation structures vary across societies with high and low incidence and prevalence of STDs? In addition to transportation, which is relevant to the spread of all infections, what are sexually relevant mechanisms that establish contact across hierarchically located subpopulations in a metapopulation? Some examples come to mind—bathhouses, conventions, "dogging" as practiced in the United Kingdom, Internet-based sex partner recruitment and group sex. Finally, what are the determinants of these mechanisms? What are the big events or slow developments that change these mechanisms—either suddenly and radically or slowly and fundamentally? Some work has already been done in the STD field on these issues[3–5] Further focus on a systematically developed research agenda along these lines may be helpful.

There are other relevant scientific developments. Norman R. Brown[6] at the University of Alberta in Calgary has been doing some interesting work on cognitive processes involved in the organization of experiential knowledge and the generation of numeric estimates. His work is highly relevant to ours particularly as we collect data on histories of sexual behavior, STD diagnoses, numbers of partners, sexual practices, and condom use. More specifically, Brown has conducted research on the multiple strategies people use in estimating event frequency and the factors that affect strategy choice. His findings suggest that men approximate and therefore overestimate their number of sex partners, whereas women enumerate and therefore underestimate their number of partners. Brown has also done work on the cognitive processes of population estimation, subjective geography, autobiographic memory, and event dating. The work on event frequency, autobiographic memory, and event dating have particular relevance to the construction of interview schedules and survey instruments in STD work; perhaps, we should follow this line of research carefully in the future.

Another very interesting and highly relevant development, particularly in the past 2 years, involves the advances in neurobiology enabled by functional magnetic resonance imaging (FMRI) and position emission tomography (PET) technologies. Multidisciplinary research (including neuroscience, anthropology, and social psychology) has focused on neurophysiological systems that relate to love using MRI technologies. Lucy Brown, Arthur Aron, and Helen Fisher's findings (among others)[7,8] indicate that romantic love may have more to do with motivation, reward, and generalized drive aspects of human behavior than with emotions or the sex drive. Subjects in the early stages of romantic love relationships showed intense activity in the reward and motivation regions of the brain, which are rich with dopamine. The researchers conclude that sex and romantic love involve quite different brain systems. This finding is counterintuitive and raises questions. For decades, sexual behavior has been conceptualized as composed of premarital, marital, extramarital, and nonmarital sex. All along, it has been implicitly assumed that love and marriage were the counterfactual and sex outside of marriage the deviation, the exception. Is it possible that neurobiology and neuron endocrinology are going to turn this conceptual scheme inside out in the new millennium?

The same research also revealed that in several brain areas, the strength of neural activity declined with the length of romance. The MRI images indicated more activity in the ventral pallidum portion of the basal ganglia in people with longer romantic relationships—the region where receptors for the hormone vasopressin (rather than dopamine) are, vasopressin being the hormone associated with attachment. Neurobiology of love includes processes that critically involve oxytocin, vasopressin, dopamine, and serotonergic signaling.[8] A senior member of this research team—Helen Fisher—distinguishes 3 primary drives that evolved for reproduction: the sex drive, romantic love, and long-term attachment—each with its associated hormones and chemical neurotransmitters in the brain: oxytocin, dopamine, and vasopressin.

Fisher's latest work shows that men and women who have been rejected by a romantic partner show increased activity in areas of the brain that link to anxiety, obsessive/compulsive behaviors, high-risk decision-making, muscle pain, and anger management. She links these findings to the crosscultural phenomena of stalking, homicide, suicide, and clinical depression as well as abandonment rage.[9] Others, including Lieberman, and colleagues from UCLA have studied the effects of rejection on the brain, particularly on the prefrontal cortex and the cingulate located in the center of the brain.[10]

The work on the biologic effects of rejection may have important implications for mechanisms underlying concurrent partnerships and short gaps between partnerships; the resolution and establishment of sex partnerships; and the sexual and health behaviors of marginalized populations, whether they are racial–ethnic minorities, those with incarceration histories, or men who have sex with men (MSM) in a context of homophobia. Other work in neuroendocrinology may also be relevant to behaviors of marginalized individuals. It appears that stressors can trigger a search for pleasure, proximity, and closeness—promoting the rebalancing of altered physiological and psychologic states.[11]

Considerable volumes of work in psychoneuroendocrinology deal with differences between men and women. Functional sex-related differences have been reported in brain correlates of emotional processing, facial processing, working memory, auditory and language processing; in the relation between stress and memory; and in the brain correlates of sexual arousal. There are also many anatomic differences between the brains of men and women. In this context, work by Larry Cahill,[12] a neurobiologist at the University of California at Irvine, is particularly interesting. Cahill has shown that neural mechanisms underlying emotionally influenced explicit recall of emotionally arousing events are different in men and women, particularly in relation to the hemispheric involvement of the human amygdala. Cahill showed, using PET scans, that even in a resting state, men's and women's brains are wired differently. Many brain areas that communicate with the amygdala in men are engaged with and respond to the external environment and the right hemisphere amygdala is more active. In women, the brain areas that communicate with the amygdala control the internal environment and the left hemisphere amygdala is more active. These findings may have implications for our interactions with our target populations and research subjects as we communicate with them for data collection, risk assessment, or behavioral intervention purposes. The take-home message in this literature is that the brain seems to be hard-wired in relation to many behaviors related to STD, *but* the causes of the hard wiring are not necessarily or purely biologic. The environment and behaviors have great impact on the hard wiring of the brain and can effectively change it.

Evolutionary psychology, which used to be known as sociobiology, has made remarkable contributions to our understanding of sexuality. This work has focused on a number of subjects, including men's and women's mating preferences; sex differences in ideal number of sex partners over a lifetime; sex differences in likelihood of agreeing to have sexual intercourse; sex differences in desirable partner characteristics; and desirable characteristics of short- and long-term mates. When asked how many sex partners they would like to have over a given period of time, men report more partners than women.[13] When asked if they would agree to have sexual intercourse with an attractive member of the opposite sex, they have known for varying lengths of time, men were only slightly disinclined to have intercourse with a woman they had known for just 1 hour; it is very unlikely that a woman would have sex with a man she has known for only this length of time. Men and women look for the same characteristics in long-term partners such as kindness, understanding, intelligence, personality, adaptability, and creativity. On the other hand, men were apparently more prepared to have casual sex with a partner of much lower intelligence than themselves compared with women. Evolutionary psychology suggests that short-term mates are selected on the basis of physical characteristics, whereas long-term mates are selected on the basis of psychologic characteristics. Men's and women's sexual strategies have evolved to enhance their reproductive success and inclusive fitness. Thus, women try to find men who will transfer resources to their offspring; "health" and "paternal investment" or "good provider" "good genes" are attributes they look for in men. Men, on the other hand, try to find women who promise rapid production of offspring and a disinclination to mate with other men; "health" "fertility" and "faithfulness" are desirable attributes in women. Interestingly, it may be beneficial from an evolutionary point of view for a woman to marry a "good provider" but mate with a man with "good genes." Many songs in the popular culture refer to this particular scenario. Evolutionary psychology also focuses on "jealousy" as a potential evolved coping mechanism for lack of commitment and on power and status behaviors in men because these may act as signals to females that the male has "good provider" attributes. Finally, based on evolutionary psychology, features men rate as attractive in a woman include symmetric face and body, full lips, small noses and a waist to hip ratio of approximately 0.7.[13]

Although macrolevel propositions of evolutionary psychology have met widespread acceptance, many of its more specific hypotheses have been challenged. Evidence of great overlaps between men and women and major variation within sexes about many sexual behavior parameters suggest that at the present moment, there are many unknowns in this domain. However, they are exciting and, perhaps, highly relevant unknowns.

Over the past 2 decades, evolutionary biology, evolutionary physiology, and biochemistry have also made remarkable advances. Just like evolutionary psychology, each of these disciplines has defined the key to understanding human sexuality as the recognition that it is an issue in evolution. Animals', plants', and humans' physiological and biochemical characteristics adapt to certain lifestyles and evolve in response to environmental conditions. Evolved sexual strategies are dependent on both ecologic parameters and the parameters of a species' biology and both sets of these parameters vary among species. In his 1997 book, *Why is Sex Fun?,* Jared Diamond described normal human sexuality as having well-defined features.[14] These include long-term sexual partnerships, coparenting, proximity to the sexual partnerships of others, private sex, concealed ovulation, extended female receptivity, sex for fun, and female menopause.

On a different but related note, the emerging field of epigenetics focuses on single nutrients, toxins, behaviors, or environmental exposures that can silence or activate a gene without altering its genetic code in any way. The environmental exposure triggers a chemical change in the body or brain that mobilizes a group of molecules—called the methyl group—the methyl group attaches to the control segment of a gene and may silence or activate the gene. Either way, the gene veers off its intended course of activity. This is called methylation.[15] Thus, we are no longer to argue whether genes or environment has a greater impact on our health, development, or behavior. They are inextricably linked. Each nutrient, interaction, or experience can manifest itself through biochemical changes that ultimately dictate gene expression whether at birth or 40 years later. Moreover, epigenetic changes can be passed from one generation to the next; and behaviors have a direct impact on hardwiring in the brain.

So where does this background of neurobiology and evolutionary psychology, both of which point to the centrality of hard wiring and evolution but at the same time emphasize the important effects of environment and behavior on biology and the brain, leave us in our understanding of human sexual behavior in the 21st century? In what follows, I briefly review current sexual behaviors and their global political economic context—the empiric evidence.

Perhaps the most widely known empiric data regarding American's current sexual behaviors is the fact that the proportion of 15- to 19-year-old men and women who have had sexual intercourse

has declined. Data from the National Survey of Family Growth indicate declines from 49% to 45% for women and 55% to 46% for men between 1995 and 2002.[16] Data from the Youth Risk Behavior Survey support the results from the National Survey of Family Growth.[17]

However, these observations are not in alignment with some other observations. For example, in very recent unpublished work, Jami Leichliter (with Kevin Fenton) compared trends in sexual behaviors in the United States and Great Britain over the decade of the 1990s and found increases in reports of heterosexual oral and anal sex and homosexual partnerships in both countries. In many cases, the increases were substantial (Jami Leichliter, personal communication, April 2006). We have reported similar increases for the general population of Seattle Washington earlier.[18] Helen Ward and colleagues reported that the rate of paid-for sex with women had doubled over the decade of the 1990s in the United Kingdom.[19] Catherine Lindsey Satterwhite compared baseline data from Project Respect and Respect 2 and found increases in reported frequency of anal sex (Catherine Lindsay Satterwhite, personal communication, April 2006). Melissa Bolyard and colleagues asked about participation in group sex events in their study of a network based sample of intravenous drug users and other adults in Bushwick and found remarkably high percentages reporting participation in group sex events, having sex in group sex events, and having unprotected sex at these events.[20]

The apparent discrepancy in these findings suggests that Americans may be simultaneously delaying sexual debut, expanding their sexual repertoire, and increasing their number of partners. Rather than measuring number of partners over lifetime, over the past 5 years or past year—all of which would be affected by the start and end dates of sexual activity—we looked at number of sex partners per sexually active life year. Data from the Seattle Sex Survey showed that younger cohorts have more sex partners per sexually active life year. This finding holds for all race–sex groups (Divya Patel, personal communication, April 2006). Data from the 2002 National Survey of Family Growth showed that the mean and median number of sex partners per sexually active life year were higher for the younger cohorts. Moreover, the variance around the central tendency measures and the maximum number of sex partners per sexually active life year also decreased consistently with age. The dose–response effect in all these measures was remarkable (Jami Leichleiter, personal communication, April 2006).

To a great extent, the higher number of partners per sexually active life year reported by younger cohorts is an age effect—human beings are more sexually active with more people when they are younger. However, the data suggest that there is a period effect indicating increases in the number of sex partners per sexually active life year between 1988 and 2002. Overall, the increases are observed in all age race groups. However, they are more pronounced among whites (Table 1).

This may explain why, despite increases in numbers of partners per sexually active life year, rates of a viral STD—genital herpes—have declined recently. Increases in sexual risk behaviors among subpopulations marked by low prevalence of sexually transmitted infection may not lead to increases in incidence, whereas such increases among subpopulations marked by high prevalence of sexually transmitted infection may be reflected in increased STD rates.

Surrounding these behavioral changes are vast changes in demography, sex-related technology, and the global political economy. Western countries have undergone the Second Demographic Transition during the 20th century.[21] The mechanisms of action involved in the second demographic transition are multiple and multidimensional. The demographic changes include large decreases in period fertility, cohort fertility, and the total first marriage rate; strong and large increases in mean age at marriage and childbearing; divorce and union dissolution; cohabitation; proportion of extramarital birth; and maternal employment. These processes are accompanied by massive migrations from developing to developed countries.

TABLE 1. Trends in Median Number of Partners per Sexually Active Life Year (NSFG)

	1988	1995	2002
White, non-Hispanic			
15–24 yrs	0.86	0.86	0.92
25–34 yrs	0.28	0.34	0.36
35–44 yrs	0.10	0.18	0.19
Black, non-Hispanic			
15–24 yrs	0.80	0.86	0.84
25–34 yrs	0.32	0.36	0.38
35–44 yrs	0.18	0.22	0.21
Hispanic			
15–24 yrs	0.73	0.59	0.60
25–34 yrs	0.19	0.21	0.21
35–44 yrs	0.07	0.11	0.12

Note. NSFG uses 50 partners as the maximum number of partners that can be reported. Table includes only those who reported at least one lifetime sex partner. NSFG did not oversample for Hispanic women in 1988.
NSFG indicates National Survey of Family Growth.

Technologic advances impact sexual behaviors. Internet-based sex partner recruitment among MSM is well known, but apparently women are also affected. Women account for more than one fourth of all visitors to sites with adult content; more than 10 million women logged onto such sites during the month of December 2003. Online purchases of sex toys by women apparently soared in the past 4 years perhaps as a result of changing expectations about sex and the privacy provided by the Internet. Anthropologists increasingly report on Tupperware-style demonstrations of sex toys.[21] It is likely that text messaging or Bluetooth-enabled cell phones will have a greater impact on sexual behaviors because cell phones are more easily accessible to masses of young people.

Mass media also affect sexual behaviors. Jane Brown and colleagues reported that white teens who had a high "sexual media diet" when they were 12 to 14 years of age were more than twice as likely to have had sexual intercourse 2 years later compared with teens with less sexual exposure.[22] The relationship was not as strong for black teens as for whites.

The frequently criticized economic aspects of globalization, which seem to result in increased inequality within and between societies have led to the expansion of so-called "black" economies. Organized crime seems to be expanding in all domains and has become increasingly involved in the trafficking of children and young women, mostly for sexual purposes. Because organized crime assures that commercial sex is available and widely accessible in acceptable ways and at an acceptable cost, the volume of such sexual transaction expands. Attitudes toward and practice of nonconventional sexual behaviors appear to be changing rapidly. For example, anecdotal evidence suggests that in the United States, some junior high school students have oral sex in the classroom. Sexual behaviors are apparently changing in response to these demographic and technologic trends, globalization, and the changes in political economy.

Neurobiology, evolutionary psychology, and epigenetics tell us that the hard wiring in the brain is highly responsive to environ-

mental and behavioral change. What is the correct interpretation of the observed trends in sexual behavior in the context of advances in neurobiology, evolutionary psychology, and epigenetics? Is it possible that we are in an era that is redefining human sexuality? Is it possible that some of Jared Diamonds' defining features of long-term sexual partnerships, coparenting, proximity to the sexual partnerships of others, private sex, concealed ovulation, extended female receptivity, sex for fun, and female menopause no longer hold? Only time will tell.

In conclusion, the current intellectual milieu is very different than the one in which my STD career started. The speed with which behaviors and their social, economic context change has accelerated manyfold and the rate at which science and technology advance has certainly multiplied. The implications of these changes for the social and behavioral aspects of sexually transmitted infection epidemiology and prevention are vast. The only way we in the STD field can keep up is by being active, alert, and perhaps aggressive observers and translators.

References

1. Watts DJ, Muhamad R, Medina DC, Dodds PS. Multiscale, resurgent epidemics in a hierarchical metapopulation model. PNAS 2005; 102:11157–11162.
2. Bailey NTJ. The Mathematical Theory of Infectious Diseases and Its Applications. New York: Hafner.
3. Kraut-Becher JR, Aral SO. Patterns of age mixing and sexually transmitted infections. Int J STD AIDS 2006; 17:378–383.
4. Kerani RP, Golden MR, Whittington WLH, Handsfield HH, Hogben M, Holmes KK. Spatial bridges for the importation of gonorrhea and chlamydial infection. Sex Transm Dis 2003; 30:742–749.
5. Bernstein KT, Curriero FC, Jennings JM, Olthoff G, Erbelding EJ, Zenilman J. Defining core gonorrhea transmission utilizing spatial data. Am J Epidemiol 160:51–58.
6. Brown NR. Encoding, representing, and estimating event frequencies strategy perspective. In: Sedlmeier P, Betsch T, eds. Frequency Process Cognition. Oxford, 2002:37–53.
7. Aron A, Fisher HE, Mashek DJ, Strong G, Li HF, Brown LL. Reward, motivation and emotion systems associated with early-stage intense romantic love: An fMRI study. J Neurophysiol 94:327–337.
8. Esch T, Stefano GB. The neurobiology of love. Neuroendocrinology Letters 2005; 26:175–192.
9. Fisher HE, Aron A, Mashek DJ, Strong G, Li HF, Brown LL. Motivation and emotion systems associated with romantic love following rejection: An fMRI study. Poster presented at the Annual Meeting of the Society for Neuroscience, Washington, DC, November 15, 2005.
10. Eisenberger NI, Lieberman MD, Williams KD. Does rejection hurt? An fMRI study of social exclusion. Science 2003; 302:290–292.
11. Goeders NE. Stress, motivation, and drug addiction. Current Directions in Psychological Science 2004; 13:33–35.
12. Cahill L. Sex-related influences on the neurobiology of emotionally influenced memory. Ann NY Acad Sci 2003; 985:163–173.
13. Buss DM, Schmitt DP. Sexual strategies theory: An evolutionary perspective on human mating. Psychol Rev 1993; 100:204–232.
14. Diamond JM. Why Is Sex Fun? The Evolution of Human Sexuality. New York: Basic Books, 1997.
15. Van de Vijver G, Van Speybroeck L, De Vaele D. Epigenetics: A challenge for genetics, evolution, and development? Ann NY Acad Sci 2002; 981:1–6.
16. Abma JC, Martinez GM, Mosher WD, Dawson BS. Teenagers in the United States: Sexual activity, contraceptive use, and childbearing, 2002 National Center for Health Statistics Vital Health Stat 2004; 23.
17. Youth Risk Behavior Survey (YRBS). Available at: http://apps.nccd.cdc.gov/yrbs/. April 2006.
18. Aral SO, Patel DA, Holmes KK, Foxman B. Temporal trends in sexual behaviors and sexually transmitted disease history among 18 to 39 years old Seattle, Washington, residents: Results of random digit-dial surveys. Sex Transm Dis 2005; 32:710–717.
19. Ward H, Mercer CH, Wellings K, et al. Who pays for sex? An analysis of the increasing prevalence of female commercial sex contacts among men in Britain. Sex Transm Infect 2005; 81:467–471.
20. Bolyard M, Friedman SR, Maslow C, et al. Describing group sex participants and events. Sex Transm Dis. In press.
21. Aral SO, Ward H. Modern day influences on sexual behavior. In: Zenilman JM, Moellering RC Jr, eds. Sex Transm Infect 2005; 19:297–309.
22. Brown JD, L'Engle KL, Pardun CJ, Guo G, Kenneavy K, Jackson C. Sexy media matter: Exposure to sexual content in music, movies, television, and magazines predicts black and white adolescents' sexual behavior. Pediatrics 2006; 117:1018–1027.