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MARRIAGE, DIVORCE, AND MALE TESTOSTERONE

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Abstract

Among male Air Force veterans of the Vietnam era, age-adjusted testosterone (T) levels are lower in married men than among those who are single or divorced. Contrary to the assumption of some sociological studies, age-adjusted T is not constant over time. T is relatively high during the years surrounding a divorce, and T level falls during the years surrounding marriage. Changing T levels may explain the low criminality found among married men, and the increase in wife abuse around the time of divorce.

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MARRIAGE, DIVORCE, AND MALE TESTOSTERONE

Married men, living stably with their wives, are less prone to crime than unmarried men (Sampson and Laub 1990, 1993; Horney, et al. 1995). Married men are less likely than single men of the same age to kill an unrelated male; divorced men exhibit homicide rates similar to single men of their age (Daley and Wilson 1990). Nonetheless, wife abuse is a serious problem (Straus and Gelles 1990), and men's violence against their wives -- but not women's violence against husbands -- is especially high around the time of divorce or separation (Wallace 1986; Allen 1990; Wilson and Daly 1993).

Without doubting the purely social mechanisms linking marital status to antisocial behavior in men, there is reason to consider, in addition, possible hormonal mechanisms. Using an unusually large cross-sectional data set of nearly 4,500 male Army veterans of the Vietnam period, Booth and his associates have shown that divorced men have higher testosterone (T) than married men of the same age (Booth and Osgood 1993; Booth and Dabbs 1993). Experiments on animals show that heightened T causes aggressive or dominating behavior in males (reviewed by Svare 1983, and Monaghan and Glickman 1992). Numerous correlational studies link T to aggressive, dominating, or antisocial behavior in men (Dabbs and Morris 1990; Kemper 1990; Booth and Osgood 1993; Booth and Dabbs 1993; Mazur 1995; Mazur and Booth 1997).

T seems not only a cause but an effect of dominating behavior, responding to situations of challenge or confrontation. Several studies of young men in athletic and game competitions show that after their contests, T increases in winners and declines in losers (Mazur and Lamb 1980; Elias 1981; Campbell, et al. 1988; Booth, et al. 1989; Gladue, et al. 1989; Mazur, et al. 1992). Also, contestants show rises in T before their contests, as if in anticipation of the competition (Booth, et al. 1989; Mazur, et al. 1992). Therefore it is difficult to interpret correlations between T and behavior. Which causes which, or are both caused by a third factor?

One or more of these possibilities might be eliminated by establishing a clear time sequence in the variations, for example, by showing that changes in behavior invariably follow rather than precede changes in hormone level, in which case the behavior cannot be the cause of the hormone level. Such unambiguous time sequences are rare, however, because the accuracy and timing of measurements are crude, and because hormones and behavior often interact, affecting one another nearly simultaneously.

One way around this difficulty is to assume that each man's T measurements represent short-term fluctuations around his characteristic basal level, which is genetically based, and that by adolescence or shortly afterward, this basal level is more or less consistent from year to year. Indeed, reliabilities from $r = .50$ to $r = .65$ are reported for T measurements taken (at the same time of day to control for circadian variation) over periods ranging from days to six years (Booth and Dabbs 1993) support the notion of ordinal (if not absolute) consistency. By this assumption, basal T level necessarily predates any post-adolescent behavior, such as marriage or divorce, and so cannot be a consequence of that behavior. Furthermore, since basal levels are assumed stable over time, it would follow that they can be adequately measured at any time, whether before or after the behavior, and therefore can be adequately assessed in a cross-sectional study. Going further, basal hormone level is regarded as a *prima facie* cause of any post-adolescent behavior that it predicts, especially if the effect persists after controlling for alternate explanations.

Specifically, in the large cross-sectional study of Army veterans, mentioned above, men with low T were more likely to marry than men with high T. Furthermore, among married men, those with high T were more likely to report hitting or throwing things at their wives, to leave home because of trouble with their wives, to have extra-marital sex, and to get a divorce (Booth and Osgood 1993; Booth and Dabbs 1993). Under the basal model, the inference is easily made that T level is a *cause* of stable marriage or of divorce.

Nearly all studies on adult humans relating T to behavior involve measurements taken at one point in time or over a short span of time, leaving untested the assumption of a consistent relationship over time between basal T level and adult behavior. Here we test this premise, using panel data spanning a decade of measurement. We also test an alternate possibility, that T level is an *effect* of marriage or divorce.

METHODS

The Air Force Health Study (not to be confused with the Army study already mentioned) is intended to evaluate health effects of exposure to Agent Orange during the Vietnam War. It compares air and ground crewmen involved in wartime herbicide spraying (denoted Ranch Hands) with matched Air Force veterans involved in other transport aircraft missions in Southeast Asia (Wolfe, et al. 1990; Henriksen, et al. in press). Ranch Hands and designated comparison subjects were invited in 1982 for a baseline personal interview, physical examination, and psychological testing, and they were invited again in 1985, 1987, and 1992 (with future cycles scheduled through 2002). With their expenses paid, men traveled for their medical examinations to the Kelsey-Seybold Clinic in Houston, TX in 1982 and to Scripps Clinic and Research Foundation in LaJolla, CA in 1985, 1987 and 1992. There was little difference between men who participated in the physical examination and those who refused in terms of reported health status, medication use, and days lost from work. Other factors which might have affected participation, including distance to the examination site, and reluctance to spend time away from family or job, were not tested.

Comparison subjects lost from the panel were replaced, and additional Ranch Hands have been located and added, so that sample size has remained fairly consistent at about 2,100 men. All four cycles were completed by 1,881 men, who are the subjects for this study. (In each cycle, data were missing for a small number of men.) There are few discernible differences in the health of Ranch Hands and comparison subjects. Although not a random sample, we believe these men are typical of Air Force transport crews serving in Southeast Asia during the Vietnam War period. The men show reasonable variation on demographic and hormonal characteristics (Table 1). It is worth emphasizing that these men were not young during the study, their ages ranging from 32 to 68 years at its outset in 1982.

Testosterone

T was assayed in duplicate from morning blood samples after an overnight fast. Quality control procedures required that when the coefficient of variation (CV) between duplicates was greater than 8%, these were re-run. We estimate mean CV between duplicates to be 5%. Means and standard deviations for T, none of them unusual, are shown by cycle in Table 1.

Raw T values, expressed as nanograms of T per deciliter of serum, are adjusted to remove the effects of aging and of cycle-to-cycle differences for extraneous reasons such as different calibration of assays. (Hormone measurements must be calibrated anew for each batch of blood samples, so batch-to-batch variation introduces measurement error.) Since adjusted T does not decline with age, its use simplifies the analysis and presentation of results. Analyses were repeated using raw T values and produced substantively similar results.

Table 1. Mean (and standard deviation) or percentages of relevant variables by cycle.

CYCLE:	<u>1982</u>	<u>1985</u>	<u>1987</u>	<u>1992</u>
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N	1880	1873	1879	1870
T (ng/dl)	639	601	538	518
	(179)	(206)	(166)	(190)
Adjusted T	570	570	570	570
(ng/dl)	(176)	(197)	(159)	(189)

Age (Yrs)	43.8	46.8	48.8	53.8
	(7.6)	(7.6)	(7.6)	(7.6)

EDUCATION

High school	49%	Same	same	Same
Assoc. Arts	9			
Bachelors +	<u>42</u>			
	100%			

RACE

(% black)	6%	6%	6%	6%
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MARITAL

Married	86%	84	84	82
Div/Sep	10	12	13	14
Widowed	1	1	1	2
Never married	<u>3</u>	<u>3</u>	<u>2</u>	<u>2</u>

100%

100%

100%

100%

Adjusted T was calculated as follows. For each cycle, T was regressed on age, producing these coefficients (in units of ng/dl/year): -4.4 for 1982, -7.8 for 1985, -6.1 for 1987, and -2.4 for 1992 ($p = .0001$). (Fits are not generally improved by a log transformation of T or by adding a quadratic age term.) These coefficients were used to convert raw T values in each cycle to age-controlled values (thus making each man's T equivalent to that of a 48 year old, the mean age across all cycles). For each cycle a constant was calculated by subtracting its mean age-controlled T from 570 ng/dl (which is the mean age-controlled T over all cycles). "Adjusted T" is formed by adding this constant to the age-controlled T. (In a few instances where values of adjusted T are implausibly low, they are converted to 29 ng/dl, the lowest raw T that was measured.) Regressing adjusted T on age produces a coefficient that is virtually zero, showing that the age effect is removed. Mean adjusted T for each cycle is necessarily 570 ng/dl, eliminating extraneous differences in calibration across cycles.

Nonhormonal Measures

Respondents reported their marital status at each cycle as married, divorced, widowed, separated, or never married; they also reported dates of changes in marital status. We combine separated men with divorced men, who were about three times more numerous, and will hereafter refer to them all as divorced.

Socioeconomic status (as measured by education or income), age, and race are known to predict divorce (Booth and Edwards 1985; Bumpass, Martin, and Sweet 1991; South and Lloyd 1995). Education is included here as a control variable (with ordinal coding: high school, AA degree, bachelors degree, graduate degree). Race is coded 1 if black, 0 if nonblack (with Hispanics included in both categories). The variable Ranchhand is coded 1 for men of that designation, 0 for men of the comparison group.

Percent body fat, known to be inversely related to T (Mazur 1995), is calculated in all cycles except 1985 according to the formula, *Percent body fat* = $[Weight (kg)/Height (m)^2] \times 1.264 - 13.305$ (Knapik, et al. 1983) for use as a control variable.

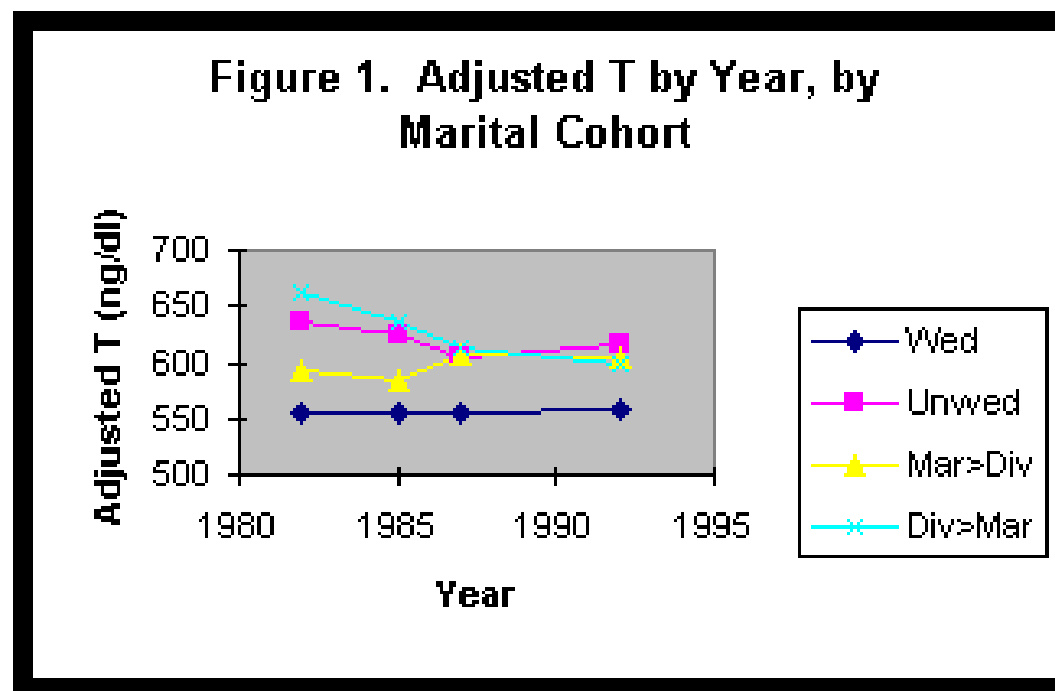
RESULTS

Variability of T Over Time

Variability of T measurements across the four cycles is assessed with Pearson correlations. The six possible intercycle correlations for T range from $r = .48$ to $.61$ (each $p = .0001$), with a mean $r = .55$; the correlation across the decade, from 1982 to 1992, is $r = .50$ (Adjusted Ts show virtually the same correlations.) Thus T variability is consistent with that previously reported over a six year period (Booth and Dabbs 1993).

T and Marital Status

Figure 1 shows adjusted T across cycles for men in four marital status categories, who together constitute 89% of the sample. The largest category ($n = 1,336$), labeled "Wed", consists of all men who were wedded by 1982 and remained so through 1992. These stably married men, graphed with a thick solid line, have consistently the lowest mean T of all categories.



----- Figure 1 -----

The next largest category ($n = 139$), labeled "Unwed" and represented by a thick dashed line, consists of men who were not married in 1982 and remained unwed through 1992. This category combines men who had been divorced since 1982 ($n = 92$) and those never married ($n = 47$) because their T levels, and trends, are not significantly different by a repeated-measures ANOVA. These continually unwed men have consistently higher adjusted T than do married men ($p = .0001$, repeated-measures ANOVA). Thus, being married is associated with low T, being single with high T.

Also shown in Figure 1 are two categories who changed marital status during the study and are sufficiently numerous for statistical analysis. One labeled "Mar>Div" ($n = 126$) was married in 1982, then divorced and did not remarry through 1992. The other, labeled "Div>Mar" ($n = 77$), was divorced in 1982, then married and remained so through 1992. Their adjusted T levels are not significantly different from each other or from the Unwed category. They are, however, consistently and significantly higher than Wed levels ($p < .002$, repeated-measures ANOVA). The decline across cycles in Div>Wed's adjusted T gives a significant time interaction when compared with Wed ($p = .0001$) and with Mar>Div ($p = .01$) but not with Unwed. In brief, adjusted T in men who were unmarried throughout the study was not much different than in men who changed marital status, but all of these men had consistently higher adjusted T than stably married men.

To control for possible confounding factors, for each cycle, adjusted T was regressed on current marital status (married or not), education, race, percent body fat (unavailable for the 1985 cycle), and Ranchhand. At every cycle, the adjusted T of married men was 40 to 60 ng/dl lower than that of unmarried men ($p < .0001$ for 1982, 1985 and 1987; $p = .0003$ for 1992).

Predicting Divorce

Does high T predict divorce? A variable $DIVORCE_i$ is defined at the i th cycle (divorced = 1, married = 0) for all men *who have been married and have not previously reported being divorced*. For the $i = 1982$ cycle, this includes all men reporting they were married or divorced; in subsequent cycles ($i = 1985, 1987$, or 1992), only married and divorced men *who reported being married on the prior cycle* are included. Therefore, $DIVORCE_i$ indicates whether or not a previously married man first enters our records as a divorcee.

$DIVORCE_i$ is regressed on adjusted T, with education, race, age, and Ranchhand included as controls. Using the $i = 1985$ cycle as an example, the regression equation has the functional form, $DIVORCE_{1985} = f(T_j, Education, Race, Age, Ranchhand)$. The subscript j refers to hormone measurement at the j th cycle. This equation is estimated four times, each time using T as measured at a different cycle. Thus, T is sometimes measured before and sometimes after the divorce. We follow this strategy in order to evaluate the effects of time leads and lags between hormone measurement and divorce. The equation is estimated 16 times altogether.

Table 2 shows 16 standardized logistic regression coefficients for adjusted T. The top row corresponds to $DIVORCE_{1982}$. Columns correspond to j , the year of T measurement. For example, the upper-left entry is the coefficient of adjusted T as measured in 1982, when predicting $DIVORCE_{1982}$. (For simplicity, control variable coefficients are not shown.)

Table 2. $DIVORCE$ is regressed on adjusted T and control variables. Shown are standardized logistic regression coefficients for adjusted T, by year of measurement. (* $p < .10$; ** $p < .01$; *** $p < .001$; **** $p < .0001$)

	<u>1982</u>	<u>1985</u>	<u>1987</u>	<u>1992</u>
$DIVORCE_{1982}$:	.24****	.13***	.12**	.13***
(191 splits)				
$DIVORCE_{1985}$:	.12*	.18**	.10*	-.07
(79 splits)				
$DIVORCE_{1987}$:	.17**	.26***	.32****	.12
(52 splits)				
$DIVORCE_{1992}$:	.00	-.05	.06	.10*

(81 splits)

The 16 coefficients for adjusted T are almost uniformly positive and mostly significant, indicating that high T correlates with divorce. The benefit of measuring T at different times allows us to go further, and we may see that for each cycle (row), the coefficients are strongest and most significant when T is measured in years immediately before and especially immediately after the divorce (boldface entries). For example, for divorces occurring in the period 1985-87, which are coded in $DIVORCE_{1987}$, the coefficient for adjusted T is highest (.32) when T is measured in 1987, immediately afterward, and its next highest value (.26) is associated with T measured in 1985, just before. To a lesser extent, this pattern occurs in each wave. Thus, basal T is not as strongly related to the divorce event as is T measured nearly contemporaneously.

Survival Analysis

Similar results appear when divorces occurring yearly across the decade of the study are examined with survival analysis, which is a class of statistical methods for studying the occurrence and timing of events such as deaths or divorces. A proportional hazards model was applied to 1,463 men who were married at the first cycle and then either divorced and did not remarry by the last cycle ($n = 126$), or remained married (Allison 1995). Divorced men were right censored (i.e., no longer analyzed) after their date of divorce. The model was estimated four times, once for each cycle's measurement of T. Education, race, age, and Ranchhand were included as control variables. Adjusted T has a consistently positive and significant effect on divorce: $p = .01$ (Wald chi-square) when T is measured in 1982, $p = .05$ when measured in 1985, $p = .0002$ in 1987, and $p = .02$ in 1992.

Since T significantly predicts the hazard of divorce, it is worth comparing survival functions for "high T" and "low T" men by dividing them at the median level of adjusted T. Survival functions are roughly similar irrespective of the cycle in which T is measured (Table 3). However visual inspection of functions based on the 1982 T measurement, compared with those based on the 1992 measurement (Figure 2), suggests that adjusted T is a slightly stronger predictor of survival differences during years close to the time of measurement.

Table 3. Survival functions for High T and Low T men, for T measured at each cycle.

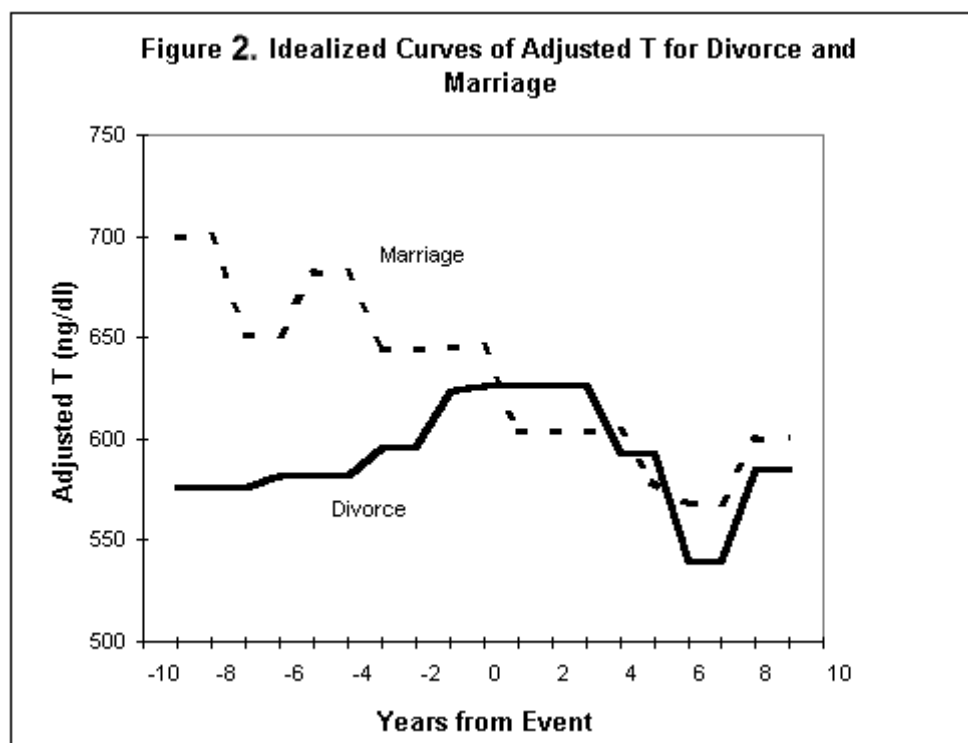
Year	T in 1982			T in 1985			T in 1987			T in 1992		
	HighT	LowT	Diff	HighT	LowT	Diff	HighT	LowT	Diff	HighT	LowT	Diff
1982	1	0.99	-0.01	1	0.99	-0.01	1	0.99	-0.01	1	0.99	-0.01
1983	0.99	0.99	0	0.99	0.99	0	0.99	0.99	0	0.99	0.99	0
1984	0.97	0.99	0.02	0.98	0.98	0	0.98	0.99	0.01	0.97	0.99	0.02
1985	0.97	0.99	0.02	0.97	0.98	0.01	0.97	0.98	0.01	0.97	0.98	0.01
1986	0.96	0.98	0.02	0.96	0.98	0.02	0.96	0.98	0.02	0.96	0.98	0.02
1987	0.95	0.97	0.02	0.96	0.97	0.01	0.95	0.97	0.02	0.95	0.97	0.02
1988	0.94	0.97	0.03	0.95	0.97	0.02	0.94	0.97	0.03	0.95	0.97	0.02
1989	0.94	0.96	0.02	0.95	0.96	0.01	0.94	0.97	0.03	0.94	0.96	0.02
1990	0.93	0.95	0.02	0.94	0.95	0.01	0.93	0.96	0.03	0.93	0.96	0.03
1991	0.92	0.95	0.03	0.92	0.95	0.03	0.92	0.95	0.03	0.91	0.95	0.04

1992 0.92 0.94 0.02 0.92 0.94 0.02 0.92 0.94 0.02 0.91 0.95 **0.04**

A survival analysis of 169 men who were divorced in 1982, of whom 77 remarried during the study, showed no significant effects of adjusted T on remarriage.

Idealized Functions

We constructed an idealized function, showing adjusted T over the years before and after divorce, as follows. Data are used from 126 men who were married in 1982, who then divorced and did not remarry as of 1992. Each man's year of divorce is designated year 0. His four T measurements are then dated by the number of years (plus or minus) from year 0. Combining all divorced men, we calculated mean adjusted T for each year, obtaining estimates for as early as ten years before 0 (for men who divorced in 1992) and as late as ten years afterward (for men who divorced in 1982). The resulting curve, consisting of 21 points, is smoothed by repeatedly running medians (three points at a time) and finally eliminating end points, producing the idealized (solid) curve shown in Figure 2. This curve shows T to be especially high during the years immediately surrounding divorce.



-- Figure 2 --

An idealized function showing adjusted T over the years before and after marriage was constructed the same way, using data from 77 men who were divorced in 1982, then married and remained so as of 1992. This function, shown as a dashed curve in Figure 3, declines throughout the years surrounding marriage.

As an alternative means of constructing idealized functions, we used OLS regression to fit polynomial functions of time, up to the third power, to the above data. For the 126 men who divorced during the study, only the quadratic term is significant ($p = .01$). The best fit equation is $Adjusted\ T = 616.1 - .8(Time)^2$, which replicates the humped shape of the "divorce" curve in Figure 3. For the 77 men who remarried during the study, only the linear term is significant ($p = .0001$). The best fit equation is $Adjusted\ T = 630.3 - 9.6(Time)$, which replicates the downward-right slope of the "marriage" curve in Figure 3. $R^2 = .02$ for each regression, emphasizing that the duration of time before or since a change in marital status explains only a small portion of the variation in men's T levels.

DISCUSSION

Hormones plausibly explain some of the difference in men's antisocial behavior that is correlated with marital status, but the causal mechanism is ambiguous. A "basal model" assumes that an individual's T level is fairly constant, and that measurements at different points in time are equally effective in predicting behavior. It explains the relatively low T observed among married men as a consequence of the antisocial tendency of men with high T to avoid marriage or be unsuccessful at it and seek a divorce.

In contrast, a "reciprocal model" assumes that an individual's T is influenced by episodes of dominance and competition. The stability of T over time is explained as the result of situational factors usually remaining fairly constant. The low T of married men is seen as an effect of stable marriage, not as a cause of it.

Which model is correct? Both can claim some support in the results presented here. Consistent with the basal model, most correlations between divorce and T are positive and significant, irrespective of the cycle in which T is measured (Table 2). Also, survival functions do not change much when different years of measurement are compared (Table 3). On the other hand, correlations between T and divorce are stronger the closer in time the hormone measurement is to the divorce, as expected from the reciprocal model. Also, marriage survival rates are slightly more differentiated in years near the hormone measurement than in years farther away (Figure 2).

The findings most difficult to reconcile with the basal model are the changes in age-adjusted T across marriage and divorce (Figure 3). These curves illustrate the dynamic nature of T, elevated in the years surrounding divorce, and declining through the years surrounding marriage. The humped nature of the divorce curve suggests that after five or six years, when the competition and argument accompanying separation are past, the adjusted T of divorced men diminishes to the level of married men. (Removing the age adjustment would superimpose an additional downward slant on all T trends.)

We do not equate marriage or divorce with a win or loss, but we assume that they *are* associated with different levels of competition. Presumably, normal marriages are secure and supportive, freer from competitive stress than single life. (Consistent with this assumption, cortisol, the "stress hormone," was lower among wed than unwed men in the two cycles when it was measured ($p = .001$).) Single men spend more time in male company than do married men, and they are more likely than married men to encounter confrontations and challenges. Lacking the social support of a wife, they are more likely to face situations where they must watch out for themselves, acting defensively and adopting protective postures. These are

precisely the kinds of situations in which T elevates (Mazur 1985). The marriage ceremony is the culmination of a more gradual period of courtship and engagement, in which a man accepts the support and consortship of his partner, removing himself from competition with other men for sexual partners. As a result, according to the reciprocal model, his T declines. In contrast, impending divorce is a time of competition between spouses for children, for material possessions, and for self respect. Also, it is a time when the divorcing husband may re-enter the competitive arena for sexual partners. According to the reciprocal model, competition elevates male T.

It might be thought that changes in T over the male life course are related to changes in sexual behavior, since both decrease with age (Edwards and Booth 1994; McKinlay and Feldman 1994). However, most relevant studies show that T level does not correlated with sexual activity (as long as T is not subnormal; reviewed in Mazur and Booth, in press). Specifically, age-related declines in male T explain little of the age-related declines in sexual behavior (Tsitouras, et al. 1982; Davidson, et al. 1983; Yesavage, et al. 1985; Sadowsky, et al. 1993). Furthermore, sexual behavior is more frequent in happy than unhappy marriages (Edwards and Booth 1994), which does not suggest elevated sex around the time of divorce except in cases where separation is accompanied by acquisition of a new partner. Therefore we doubt that changes in sexual behavior account for observed differences in T with marital status.

The T difference between married and unmarried men has implications for antisocial behavior. Married men, living stably with their wives, are less prone to crime than unmarried men of the same age (Sampson and Laub 1990, 1993; Daly and Wilson 1990; Horney, et al. 1995); and men's violence against their wives is relatively high around the time of divorce or separation (Wallace 1986, Allen 1990, Wilson and Daly 1993). If the reciprocal model is correct, then perhaps male antisocial tendencies change with marital status partly because men's T levels change with marital status. Married men, with lower T than unmarried men of the same age, would be expected to exhibit lower criminality than unmarried men. If husbands' T rises with the prospect of divorce, this elevation may partly explain the increase in wife abuse at that time. These changes in hormone level are large enough in magnitude to plausibly explain differences in antisocial behavior (Booth and Osgood 1993).

The changes in antisocial behavior that follow men's changes in marital status have been explained by other researchers as consequences of a gain or loss of social integration and social control (Sampson and Laub 1990, 1993; Horney, et al. 1995). Hormonal explanations are not incompatible with social structural explanations, and they may be combined into "biosocial models" (Udry 1988, Kemper 1990, Mazur 1995). The social integration of a stable marriage may cause lowered T, which reinforces the decline in antisocial activity that is associated with marriage. Conversely, the loss of integration signaled by an impending divorce, along with the typically attendant rise in argument, produces elevated T which, in turn, supports a rise in antisocial behavior. Thus, hormonal mechanisms do not replace sociological explanations but complement them, giving us a more elaborate understanding of their operation.

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