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Review

The puzzle of monogamous marriage

Joseph Henrich[1,2,*], Robert Boyd[3] and Peter J. Richerson[4]

[1]*Department of Psychology, and* [2]*Department of Economics, University of British Columbia, British Columbia, Canada*
[3]*Department of Anthropology, University of California Los Angeles, Los Angeles, CA, USA*
[4]*Department of Environmental Science and Policy, University of California Davis, Davis, CA, USA*

The anthropological record indicates that approximately 85 per cent of human societies have permitted men to have more than one wife (polygynous marriage), and both empirical and evolutionary considerations suggest that large absolute differences in wealth should favour more polygynous marriages. Yet, monogamous marriage has spread across Europe, and more recently across the globe, even as absolute wealth differences have expanded. Here, we develop and explore the hypothesis that the norms and institutions that compose the modern package of monogamous marriage have been favoured by cultural evolution because of their group-beneficial effects—promoting success in inter-group competition. In suppressing intrasexual competition and reducing the size of the pool of unmarried men, normative monogamy reduces crime rates, including rape, murder, assault, robbery and fraud, as well as decreasing personal abuses. By assuaging the competition for younger brides, normative monogamy decreases (i) the spousal age gap, (ii) fertility, and (iii) gender inequality. By shifting male efforts from seeking wives to paternal investment, normative monogamy increases savings, child investment and economic productivity. By increasing the relatedness within households, normative monogamy reduces intra-household conflict, leading to lower rates of child neglect, abuse, accidental death and homicide. These predictions are tested using converging lines of evidence from across the human sciences.

Keywords: cultural group selection; monogamy; polygyny; marriage; norms; institutional evolution

1. INTRODUCTION

Approximately 85 per cent of societies in the anthropological record permit men to marry multiple wives [1]. Taking wives is always positively associated with status, wealth or nobility [2], even among highly egalitarian foraging societies [3]. After the origins of agriculture, as human societies grew in size, complexity and inequality, levels of polygynous marriage intensified, reaching extremes in the earliest empires whose rulers assembled immense harems [4,5]. Today, however, with absolute wealth gaps greater than any seen in human history, monogamous marriage is both normative and legally enforced in most of the world's highly developed countries. While the roots of the package of norms and institutions that constitute modern marriage can be traced back to classical Greece and Rome [6,7], the global spread of this peculiar marriage system [6] has occurred only in recent centuries, as other societies sought to emulate the West, with laws prohibiting polygyny arriving in 1880 in Japan, 1953 in China, 1955 in India and 1963 in Nepal. Given its historical rarity and apparent ill-fit with much of our evolved psychology, why has this marriage package spread so successfully? Historically, the emergence of monogamous marriage is particularly puzzling since the very men who most benefit from polygynous marriage—wealthy aristocrats—are often those most influential in setting norms and shaping laws. Yet, here we are.

This paper develops and tests the hypothesis that the modern package of norms and institutions that constitutes monogamous marriage has been shaped by cultural evolution driven by inter-group competition—a set of processes termed cultural group selection [8]. The idea is that competition among communities—such as nations, polities or religious organizations—favours those norms, values, beliefs, practices and institutions that most effectively harness, reinforce and shape our motivations and behaviour in ways that generate success in inter-group competition. Over centuries, these processes can lead to the spread of social norms and institutions (formal and informal) that create societal-level benefits and reduce aggregate societal costs, thereby giving an edge in inter-group competition. Inter-group competition need not result in violent conflict as such processes can produce a differential diffusion of beliefs, norms and institutions from more successful to less successful societies [8,9]. This aspect of cultural group selection may be particularly important for spread of normative monogamy.

Researchers from biology to history have long noted the puzzle of monogamous marriage, and suggested

*Author for correspondence (joseph.henrich@gmail.com).

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that such norms spread because of their group-beneficial effects [6,10]. While historians considering the puzzle have shown how the European historical record is at least consistent with a process driven by cultural group selection, little work has focused on developing and testing predictions regarding how normative monogamy impacts individual psychology, or how (if at all) those effects aggregate up to impact groups (though see Moorad *et al.* [11]). Thus, our effort here focuses in developing the broader theoretical and empirical issues, rather than in detailing historical cases.

We pursue this hypothesis as follows. First, we distinguish *mating strategies* from *marriage systems*, and clarify which aspects of our evolved psychology can be harnessed or reinforced by cultural group selection, and which aspects need to be suppressed. Second, we develop a set of testable hypotheses and their empirical implications. We predict that imposing monogamous marriage reduces male reproductive competition and suppresses intra-sexual competition, which shrinks the size of the pool of low-status, risk-oriented, unmarried men. These effects result in (i) lower rates of crime, personal abuse, intra-household conflict and fertility, and (ii) greater parental investment (especially male), economic productivity (gross domestic product (GDP) *per capita*) and female equality. We draw on both longitudinal and cross-sectional evidence from diverse disciplines. In some cases, we provide solid empirical tests of specific predictions or implications. In other cases, the available evidence provides only qualified support, basic consistency or prima-facie plausibility. As usual, future work may find the theory wanting and specific hypotheses wrong. In closing, we (i) contrast the conditions favourable to the spread of monogamous versus polygynous marriage, (ii) consider alternative hypotheses for the spread of monogamous marriage, and (iii) speculate on how marriage systems might be linked to the rise of democratic institutions and industrial economic growth.

2. BUILDING BLOCKS

It is crucial to recognize that marriage norms are not the same as our evolved mating psychology. Humans, like all primates, possess an evolved psychology that influences our choices regarding mates, mating, reproduction and parental investment. For established evolutionary reasons, male and female mating psychologies differ in important ways. As in other primates, these different mating strategies yield a mating system (or range of systems), as individuals cooperate and compete under different ecological and economic circumstances (see electronic supplementary material). Here, we first summarize key points about human mating strategies, and then discuss marriage systems. Our approach considers how specific marriage systems might be favoured by cultural group selection because of how they harness aspects of our evolved psychology.

(a) *Mating strategies*

There is much evidence that the mating strategies of men and women differ. Like many mammals, human females invest more heavily in their offspring than males. Humans also pair-bond [12,13]—both monogamously and polygamously—in collaborations that encourage more extensive male parental investment and a division of labour. This means that men generally have higher variance in fitness than women [14]. When competition for mates is fierce, less-attractive low-status men risk being shut-out entirely from mating. Since the fitness difference between having one long-term mate and zero mates is—on average—large, low-status males should often pursue risky, high-stakes, strategies that provide some chance of avoiding fitness oblivion [15]. This means that cues that indicate intensive intra-sexual selection should spark competitive motivations, steep temporal discounting and risk proneness. Low intra-sexual competition means that nearly all males can find at least one mate, and status gains do not lead to steep increases in reproductive success. Here, pursuing safe, long-term strategies like pair-bonding is favoured—that is, men will be more risk-averse and more patient. All fathers must decide whether to invest in their offspring or in seeking additional mates. This decision should depend on paternity certainty, and on the marginal payoffs to investing in offspring versus additional matings. When the rich high-status men cannot easily gain additional mates, they should invest more in offspring (see electronic supplementary material).

Women also possess flexible mating strategies. However, their direct fitness is limited to the number of children that they can bear and rear. For our purposes, when males vary substantially in status (based on skill, resources, power, etc.), women prefer higher status males as long-term pair-bonded partners, though they may also seek 'good genes' via extra-pair copulations when pair-bonded to a low-quality male. Polygynous pair-bonding is more acceptable to women than is polyandrous pair-bonding to men. Polyandrous men face paternity uncertainty—they are rather uncertain about which children are theirs—and must compete for their mate's limited reproductive capacities (gestation, lactation, etc.). Polygynously mated women face neither maternal uncertainty nor (usually) competition for their mate's essentially unlimited sperm. This implies that under conditions in which men vary substantially in status, polygynous pair-bonding is a likely outcome of both male and female mating choices. The electronic supplementary material further details and supports these points.

(b) *Marriage systems*

Marriage systems are distinct from mating strategies. Humans, unlike other species, are heavily reliant on cultural learning for acquiring all manner of behaviours and practices, including social behaviour. Because humans also acquire the standards by which they judge others as part of this process, cultural evolution gives rise to social norms. Failure to conform to norms results in reputational damage, loss of status and various forms of sanctioning [16].

Different societies have evolved diverse sets of norms that regulate pair-bonds. Such marriage norms influence people's long-term pair-bonds, and

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thus their mating choices. Being married comes with economic, social and sexual expectations, prescriptions and prohibitions for both parties, who are accordingly evaluated—formally or informally—by their community. Marriage norms govern such areas as who (i) can marry whom (e.g. exogamy, incest taboos), (ii) pays for the marriage ritual, (iii) gets the children in the event of the groom's or bride's death, and (iv) is a 'legitimate' heir and can inherit property, titles, etc. Marriage norms also specify rules about partner number and arrangement (e.g. no group marriages). The key to understanding marriage versus pure pair-bonding is recognizing the role of a community in defining, sanctioning and enforcing marriage norms. This element of human social life is routinely missed in non-cultural approaches to monogamy [17,18].

Marriage norms are certainly not independent of our mating psychology, nor can they entirely subvert it. They can, however, influence behavioural patterns in two ways. First, humans readily internalize social norms, at least partially. This means norms become internalized such that norm adherence is intrinsically rewarding [16]. Work in neuroscience has shown how both adhering to local norms and punishing norm violators activates the brain's reward circuitry [19]. Second, the fact that people acquire and internalize norms means that norm violators can be condemned and sanctioned [20]. Sanctioning, independent of any internalization, results in norm violators suffering real costs. Thus, many marriage systems have culturally evolved to reinforce our evolved pair-bonding strategy, leading to more enduring male–female collaborations. This galvanizing effect of some marriage systems is thrown into stark relief by the existence of alternative systems like those possessed by (i) the Na in China, whose norms suppress long-term pair-bonding and operate without either marriage or paternal investment [21] or (ii) various South American societies, whose norms allow the spreading of perceived paternity, and paternal investment, across two or more fathers [22].

Of course, the prescriptions and prohibitions of marriage systems (sets of norms) and the actual mating patterns in human societies often do not match up—nor should we expect them to. Consider that some societies possess marriage norms specifying that each man and woman shall marry once in their lifetime. After marriage they shall never seek any sexual or romantic relationship with anyone else, ever, and all resources must be devoted to the good of the household. As with other norm violations like theft and lying, this never quite works out, as our evolved mating psychology gives rise to broad societal-level patterns of infidelity, divorce, prostitution, etc. But there is little doubt that particular marriage systems shape and influence the resultant mating patterns, as well as parental investment. In nineteenth century Europe, for example, non-marital fertility was so slight as to be demographically negligible despite substantial rates of late marriage and of adults who never married [23]. Thus, social norms are powerful enough to buttress our pair-bonding psychology, such that most people in a society have only one long-term mate, or to curtail almost all long-term pair-bonding, or to allow women to actively seek extra-pair copulations while repressing male jealously.

Marriage systems found throughout the anthropological record reflect and amplify aspects of our mating psychology. As noted, most human societies permit polygynous marriage in some form, including most foraging societies [3,24]. In polygynous societies, a man's social status, hunting skill, nobility and wealth lead to more wives [25].The autocratic leaders of chiefdoms, empires and early states ranging from Tonga to China consistently assembled immense harems with 100 or more women/girls [5]. Meanwhile, polyandrous marriage is relatively rare, often involves brothers marrying the same wife, and is frequently intermixed with polygynous marriages within the same population (see the electronic supplementary material).

The 15 per cent or so of societies in the anthropological record with monogamous marriage fall into two disparate categories: (i) small-scale societies inhabiting marginal environments with little status distinctions among males and (ii) some of history's largest and most successful ancient societies. Researchers have labelled these 'ecologically imposed' and 'socially imposed' forms of monogamous marriage [6,7,26]. Ecologically imposed monogamy occurs because the societies lack sufficiently large differences in male wealth or status to motivate women to become second wives. Socially imposed monogamy covers situations in which norms or laws regulate spousal number (along with inheritance and divorce rights), including circumstances in which a noble class forcibly imposes monogamous marriage on commoners while retaining polygyny for themselves (see the electronic supplementary material).

3. THEORY AND EVIDENCE

We hypothesize that as social inequalities expanded over human history and societies became increasingly complex, the group-level benefits of normative monogamous marriage increased. In relatively egalitarian societies, including most foragers, the social implications of polygynous marriages are minor. Few men in these societies achieve sufficient status to attract additional wives, and if they do, this is typically limited to one [27]. Among these foraging groups, very successful men might rarely obtain three or at most four wives [28]. For example, among tropical African foragers, the rates of polygyny range from 3 to 20 per cent [29]. Often, there are fewer older men than women due to male mortality in hunting accidents and violent conflicts, so polygynous marriages soak up any 'extra' women (for an exception see Marlowe [27]).

As the wealth and inequality of societies increased over the course of societal evolution, our evolved psychology operating through within-group cultural evolutionary processes increased the degree of polygynous marriage among the richest and most powerful men [4,28]. This increase in polygynous marriage would have led to predictable effects (see below). In the most complex societies (high-end states [30]), where a society's competitive success is influenced by its economic output, standing armies, innovation rates, trade, division of labour and offspring quality, higher rates of polygynous marriage reduce a society's competitive success. Under

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these conditions, normative monogamy increases a society's competitiveness because of how it influences crime rates, male motivations, paternal investment, fertility and economic production. Lower crime rates favour more commerce, greater investment, more freely flowing information, greater economic production and a finer division of labour. Greater paternal investment and lower fertility favour higher quality offspring. Several of these factors favour greater innovation and more rapid economic growth.

(a) *Monogamous marriage reduces the intensity of intrasexual competition*

In this section, we present and empirically assess a series of inter-related hypotheses about how the extent and intensity of polygynous marriages negatively impact a group's success, stability or competitive ability, and clarify the effects created by normative monogamy. When we refer to 'normative monogamy' below, we mean to refer to the package of norms and laws governing modern marriage, not only to rules about spousal number. In particular, the customs and laws regulating divorce (e.g. division of assets) and inheritance are important. In referring to 'polygyny', we mean 'general' or 'non-sororal' polygyny [1], which does not limit men's spousal choices to the real or classificatory sisters of one's current wife (see electronic supplementary material).

Our approach predicts that increasing the extent and intensity of polygynous marriage increases male intrasexual competition. This implies that opportunities for sexual selection will be higher in more polygynous societies. Norms and institutions requiring monogamous marriage—or reducing polygyny—should reduce the strength of sexual selection. Here, we review two lines of evidence indicating that normative monogamy reduces intra-sexual competition. First, we present evidence indicating that the intensity of intra-sexual competition declined when monogamous marriage was gradually imposed on nineteenth century Mormon communities. Then, we show that the intensity of intrasexual competition is lower in normatively monogamous societies drawn from a sample of 18 societies with diverse marriage norms.

Data from Mormon communities between 1830 and 1890 show that intra-sexual competition declined dramatically as governmental forces suppressed polygynous marriage [11] through a series of civil, legal, legislative, financial and military manoeuvres that began in the 1840s and had mostly ended by 1890, when the Latter-day Saints church officially disavowed the practice of plural marriage. The estimated ratio of the opportunities for sexual selection on males (I_m) versus that on females (I_f) provides a key measure. In 1830, I_m/I_f was 2.4, which means that males faced nearly two-and-half times the selective intensity faced by females. By the latter part of the nineteenth century, this ratio had dropped and levelled off at 1.17, indicating that men faced only slightly more competition than women. The size of intrasexual competition had dropped by more than eight times during the period when monogamous marriage was imposed. Bateman gradients, which provide a different measure, tell the same story [11].

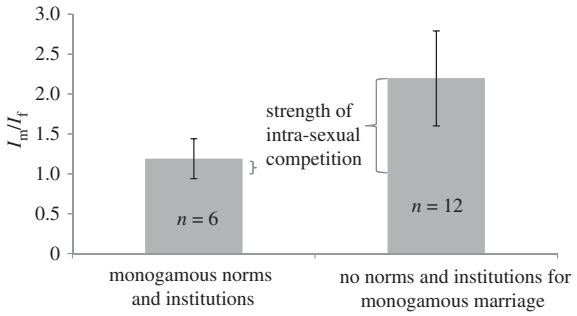

Figure 1. Comparison of the selective strength of intra sexual competition. Error bars are bootstrapped 95% CIs.

While this analysis is consistent with our hypothesis, it cannot causally isolate the effect of the imposition of monogamous marriage on intra-sexual competition because many other historical processes occurred over the same time period. However, further support emerges from comparing the I_m/I_f ratios from diverse societies [14], where the arrays of particular historical processes differ. The 1830 Mormon value of 2.4 for I_m/I_f is similar to that observed in other polygynous societies [14], such as the Yanomano of Venezuela (2.11), Arabs in Chad (2.28), or the Dogon (2.47) in Mali. The value of 1.17 among the late-nineteenth century American Mormons falls between the 1.25 of contemporary Americans and the 0.81 of historical Finland (1745–1900). Figure 1 contrasts the amount of sexual competition in societies with normative monogamy and those without it. When $I_m/I_f > 1$, males face more reproductive competition than females; the larger I_m/I_f, the fiercer is the competition. The mean values of I_m/I_f for these two subsamples indicate that opportunities for sexual selection (mate competition) are 6.4 times greater in societies lacking normative monogamy.

This combination of longitudinal and cross-sectional evidence converges to suggest that normative monogamy does indeed reduce intrasexual competition. Next, we examine whether this competitive suppression actually results in lower crime rates.

(i) *Implication: normative monogamy reduces crime*

One important implication of suppressed intrasexual competition should be reduced crime. By expanding the pool of unmarried men and elevating the degree of intrasexual competition, more polygynous marriages will increase men's discounting of the future and risk-taking, resulting in more socially undesirable behaviours. Faced with high levels of intra-sexual competition and little chance of obtaining even one long-term mate, unmarried, low-status men will heavily discount the future and more readily engage in risky status-elevating and sex-seeking behaviours. This will result in higher rates of murder, theft, rape, social disruption, kidnapping (especially of females), sexual slavery and prostitution. As a by-product, these men will probably engage in more substance abuse. Even among high-status males, competition can intensify if the fitness gradient remains steep. This can lead to risky bids for political power

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motivated by the possibility of acquiring harems. By contrast, normative monogamy drains the pool of low-status unmarried men resulting in lower rates of social ills, including reduced rates of crime, social disruption and substance abuse.

To see why even a small increase in polygyny leads to a substantial increase in men without mates, imagine a society of 40 adults consisting of 20 males and 20 females. Suppose these 20 males vary from the unemployed high-school drop outs to CEOs. Let us assume that the 12 men with the highest status marry 12 of the 20 women in monogamous marriages. Then, the top five men (25% of the population) all take a second wife, and the top two (10%) take a third wife. Finally, the top guy takes a fourth wife. This means that of all marriages, 58 per cent are monogamous. Only men in the top 10 per cent of status married more than two women. The most wives that anyone has is four. While this degree of polygyny is not extreme in cross-cultural perspective [1,3], it creates a pool of 40 per cent of the male population who are shut out of the marriage market. To even enter the marriage market, a man has to be in the top 60 per cent of male status. Doubling one's number of long-term mates (to two) then requires entering the top 25 per cent of males. By contrast, normative monogamy means that no one is shut out, and increases in a man's relative status does not increase his number of long-term mates.

Several converging lines of evidence indicate that monogamous marriage reduces crime. First, we review evidence indicating that unmarried men gather in groups, engage in personally risky behaviour (gambling, illegal drugs, alcohol abuse) and commit more serious crimes than married men. Getting married substantially reduces a man's chances of committing a crime. Second, we review cross-national data showing that polygyny leads to a higher percentage of unmarried men, and that more unmarried men is associated with higher crime rates. Then, using within-country and historical data on sex ratio, we confirm that the more unmarried men or greater intrasexual competition are associated with higher crime rates. Finally, we discuss detailed anthropological cases that are consistent with this connection.

Cross-sectional data show that unmarried men are more likely than married men to commit murder [31], robbery and rape [32,33]. Moreover, unmarried men are more likely than married men to gamble and abuse drugs/alcohol [33]. These relationships hold controlling for socioeconomic status, age and ethnicity. Of course, these data do not prove that being unmarried causes criminal behaviour because individuals who are less likely to commit crimes, or abuse substances, might also be more marriageable or more likely to want to married.

Work using longitudinal datasets strengthens the case for a causal relationship. These data allow researchers to follow the same individuals over time to see how marriage impacts their behaviour *relative* to their own pre-marital behaviour. Sampson *et al.* [34] used longitudinal data that tracked boys once in a Massachusetts reform school from age 17 to 70. Most subjects were married multiple times, which allowed the researchers to compare their likelihood of committing a crime during married versus unmarried periods of their lives, using each individual as his own control. Across all crimes, marriage reduces a man's likelihood of committing a crime by 35 per cent. For property and violent crimes, being married cuts the probability of committing a crime by half. When men are divorced *or widowed*, their crime rates go up. Analyses also show that 'good marriages' are even more prophylactic than average marriages (though marrying a criminal wife has the opposite effect). This is consistent with prior work by Sampson & Laub [35].

Using data from Nebraska inmates, Horney *et al.* [36] examined the effects on criminal propensities of entering school, getting a job, moving in with a wife, moving in with a girlfriend and using drugs or alcohol. Controlling for all of these other factors, marriage reduces a man's probability of committing a crime by roughly half. This effect is strongest for assault and weakest for property crimes, but is significant for both of these as well as drug crimes. The size of this marriage effect is similar to entering school and much stronger than being on parole or probation. Interestingly, unmarried cohabitation does not reduce crime rates. Having a job had mixed effects, none of which were particularly large. The positive effect on crime of living with a wife is even larger than the negative effect of heavy drinking (for similar results from London see the study of Farrington & West [37]).

By far, the biggest factor in increasing an individual's criminal propensities was taking drugs [36]. This suggests that Horney *et al.*'s analysis may underestimate the total impact of marriage because marriage also reduces binge drinking and use of marijuana [38]. Thus, marriage probably has both direct effects on committing crimes, and indirect effects via a reduction in personal abuses. Cohabitation also reduces substance abuse, but less effectively than does marriage.

Researchers have explored several proximate mechanisms that explain how marriage reduces crime in men (electronic supplementary material). Though speculative, one interesting mechanism suggests that marriage in monogamous (but not polygynous) societies lowers men's testosterone levels. However, the selective forces generated by cultural group selection do not 'care' why marriage reduces criminal behaviour, only that it somehow does.

While marriage may reduce an individual's chances of committing a crime or personal abuse, two other important links are required to assess whether these individual effects aggregate up to impact whole societies: (i) does greater polygyny increase the size of the pool of unmarried men? and (ii) does this in turn increase crime rates? To examine this, we establish the first link using cross-national data to show that more polygyny is associated with a larger percentage of unmarried males in the population. Then, using the same dataset, we show that the higher the percentage of unmarried men in a country, the higher the rates of rape, murder, theft, robbery and fraud. Finally, to strengthen the case for a causal relationship, we then review within-country and historical analyses of the relationship between sex ratio and crime.

To establish the link between the degree of polygyny and the percentage of unmarried men, we use

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national-level data obtained from Kanazawa & Still ([39]; 2009, unpublished data) who compiled crime statistics, demographic information and economic data from multiple sources together with a measure of the degree of polygyny for 157 countries. To create a measure of polygyny, Kanazawa and Still coded all of the cultures in the *Encyclopedia of World Cultures* on a four-point scale (from 0 = monogamy is the rule and is widespread, to 3 = polygyny is the rule and is widespread), and then developed a country-level value by aggregating all of the cultures within a country, multiplying the values for each culture by the fraction of the country's population represented by that culture. In the electronic supplementary material, we extend Kanazawa and Still's work by regressing the percentage of unmarried men (age 15 and over) in the national population on this measure of polygynous intensity with controls for economic development (GDP *per capita*), economic inequality (sectoral Gini coefficients), population density and degree of democracy in 1980, as well as dummy variables for Africa and Asia [39]. The results across six different model specifications show that the greater the degree of polygyny across nations, the higher the percentage of unmarried men. Going from a negligible degree of polygyny (polygyny = 0 nationwide) to widespread polygyny (polygyny = 3 everywhere) increases the size of this excess pool by between 13 and 27 per cent.

Making the second linkage, the electronic supplementary material also shows that the greater the percentage of unmarried men in the national population, the greater the rates of rape, murder, assault, theft and fraud, controlling for the same variables in the regression described above. The percentage of unmarried men is a highly significant predictor of all these crime rates, except assaults where it is only marginally significant. In fact, the percentage of unmarried men is the only predictor that is consistently important across all five felonies. For rape and murder, adding the percentage of unmarried men to a regression with all the other variables increases the variance explained from 33 to 45 per cent and from 12 to 24 per cent, respectively. For assault, theft and fraud, the variance explained increases by about 5 per cent when the percentage of unmarried men is added as a predictor.

While providing an important step, we should not place too much confidence in these findings because (i) the measure for the degree of polygyny is crude, (ii) the data on inequality is incomplete, and (iii) using aggregate cross-sectional data at the country level limits inferential power. More work is needed to extend this preliminary analysis. Nevertheless, these findings converge with the crime-reducing effects of marriage and with the suppression of intrasexual competition shown above. Further, given these other results, it is difficult to argue for reverse causality in these regressions, that a greater surplus of unmarried males causes more polygyny, or that more crime causes men to forgo marriage (independent of income, etc.).

Analyses done within countries allow us to further strengthen the case for a causal relationship between an excess of unmarried males and crime, while avoiding the pitfalls of cross-national analyses. Unequal sex ratios have arisen in a variety of circumstances, most notably in modern India and China, where parental preferences for sons have shifted the sex ratio in favour of males [40], and on frontiers, such as in the American West. The empirical patterns from all such diverse cases tell the same story [40,41]: unmarried low-status men, often in bachelor-bands, engage in higher levels of aggressive, violent and anti-social activities. India and China are particularly informative since the data quality permit econometric analyses aimed at assessing causal relationships.

In China, sex ratios (males to females) rose markedly from 1.053 to 1.095 between 1988 and 2004, nearly doubling the number of unmarried or 'surplus' men [42]. At the same time, crime rates nearly doubled—90 per cent of which were committed by men. An increase in sex ratio was created by the gradual implementation of China's one-child policy, as well as by the ongoing demographic transition. The fortuitous fact that different provinces implemented the policy at different times for reasons unrelated to crime rates creates an opportunity for statistical analyses of the impacts of the policy and the alterations in sex ratio it produced. The implementation date of the policy across provinces provides an exogenous variable that can be used to establish the direction of causality.

Regression analyses [42] show that a 0.01 increase in sex ratio is associated with a 3 per cent increase in property and violent crimes, controlling for a number of demographic and economic variables. These analyses also indicate that the effect arises from an increase in the number of unmarried men and not the overall number of men. Increases in inequality, unemployment and urbanization also have positive effects on crime rates, but the effect of sex ratio is independent of these. To preclude the possibility that measurement errors in sex ratio correlate with crime rates, Edlund *et al.* [42] use the implementation year of the one-child policy as an instrumental variable in a two-stage least-squares analysis. They use implementation year to predict sex ratio, and then use the predicted (unbiased) sex ratio data to predict crime. This indicates that a greater surplus of males *causes* crime rates to increase. For more details see the electronic supplementary material.

In India, Dreze & Khera [43] show that sex ratio differences across districts are strongly associated with murder rates, controlling for many other factors. The effect is large: going from a male to female ratio of 1.12 (in Uttar Pradesh) to 0.97 (in Kerala) cuts the murder rate by half. Moreover, controlling for many other factors, the authors show that males living in districts with more males relative to females are more likely to commit murders; that is, the average male gets more murderous (takes more risks) when the intrasexual competition is higher. This is important because otherwise the increase in murder rates could be attributed merely to an increase in the number of males.

Historical data also link disproportionately large shares of unmarried men to higher crime, violence and drug abuse. Drawing on a range of evidence, Courtwright [41] argues that the violent character of the American West arose principally from the large pool of unmarried men who migrated there. Variation in

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crime rates in nineteenth century America corresponds to the spatial distribution of biased sex ratios. Over time, as sex ratios move towards unity in different regions, crime rates drop in those regions. Courtwright suggests that similar cases can be made for Australia's frontier in New South Wales and for the Argentinean Pampas.

Anthropological data provide an additional line of support for this view. In many non-industrialized societies, young unmarried men form groups of marauders who go on raids to steal wealth and wives, while raping and pillaging. Polygynous societies engage in more warfare [44], often with the goal of capturing women [1]. Cross-cultural analyses, though crude, indicate that polygynous societies also have more crime relative to more monogamous societies [45]. Ethnographic cases show why this is: among the Kuria in Tanzania, young males lacking sisters—who would bring substantial bridewealth—are much more likely to engage in cattle raiding, which they see as necessary to obtain sufficient resources to enter the polygynous marriage market [46]. The electronic supplementary material provides additional anthropological material.

This line of reasoning converges with three other areas of research. First, within economics, work on tournament theory predicts that when incentive gradients are steep (e.g. winner-take-all competitions), individuals should often prefer riskier strategies, especially when they are losing or perceive themselves as unlikely to win. These decision-theoretic models [47], which hinge on the same logic as our evolutionary approach [48], predict that even those who perceive themselves as winning or likely to win often need to pursue somewhat riskier strategy when incentive gradients (analogous to fitness gradients) are steeper, because they know that those who are currently losing will be pulling out all the stops. Empirically, field evidence from mutual funds, golf [49,50], auto-racing, distance running, basketball and poker shows that probable losers take more risks, and that both the size and spread of monetary prizes predict riskier choices by everyone [51]. Mutual fund managers [52,53], for example, who find their fund's performance behind other funds in the same category at mid-year, reallocate into riskier portfolios relative to those who did well in the first half of the year (a fund's ranking influences capital inflow, which influences managers' compensation). In auto-racing [54], races with larger spreads among the prizes have more accidents (accidents occur when drivers take risks that fail). Even in the laboratory, behavioural experiments show that players who are currently losing pursue the risky strategy more frequently (unless the outcomes of risky choices are highly correlated), and the choice of the risky strategy by the leading player depends on how big his lead is [55]. This work in economics supports earlier laboratory work by evolutionary psychologists showing similar effects [56].

Second, much empirical work from public health and psychology shows how increasing the steepness of the status/income hierarchies within societies influences outcomes in ways consistent with much evolutionary theorizing. Controlling for other variables, populations with steeper income gradients (more inequality) have worse social outcomes, based on evidence related to crime, violence, drug abuse, education and longevity [57]. Several of these patterns have been examined not only across nations but also among states within the US, and even among Chicago neighbourhoods [56,58].

Third, we posited that heightened intra-sexual competition influences crime rates and personal abuses—in part—by increasing individuals' risk tolerance and temporal discounting. While these specific proximate psychological mechanisms are not crucial to the larger theory, we note that existing experimental work provides preliminary support by showing that (i) prisoners are willing to risk greater financial penalties compared with students in identical behavioural experiments [59], (ii) inter-temporal choice experiments show that both drug addicts and smokers discount the future more steeply than control groups [60,61], and (iii) risk-preference experiments indicate that drug users are less risk-averse compared with non-users [62]. Thus, such preliminary evidence suggests that crimes and personal abuses tend to be committed more by those who are relatively more inclined towards risky choices and future discounting.

(ii) *Implication: monogamous marriage reduces the spousal age gap, gender inequality and fertility*

Polygynous marriage increases competition for wives, as married men remain on the marriage market. This increased competition drives down the age of first marriage for females and increases the spousal age gap. The reduced supply of unmarried women, who are absorbed into polygynous marriages, causes men of all ages to pursue younger and younger women. The competition also motivates men to use whatever connections, advantages or alliances they have in order to obtain wives, including striking financial and reciprocal bargains with the fathers and brothers of unmarried females (see electronic supplementary material for North American examples). Once adolescent girls and young women become wives, older husbands strive to 'protect' their young wives from other males (guarding the paternity of any offspring) and dominate household decision-making. More competition also motivates men to seek to control their female relatives (e.g. sisters), as demand for wives increases. This results in suppressing women's freedoms, increasing gender inequality and stimulating domestic violence. Women's loss of influence on household decision-making and their lower age of marriage results in higher fertility. By contrast, normative monogamy diffuses the pressure to bring younger brides into the marriage market, and thereby reduces the spousal age gap, male efforts to control ('protect') women, gender inequality and total fertility. We address below whether the effects on gender equality or the spousal age gap create—in themselves—any group-level benefits.

Table 1 compares (i) highly polygynous countries (HPCs) in which more than 10 per cent of married men have two or more wives, (ii) less-polygynous African countries (LPACs) in which less than 10 per cent of married men have two or more wives, (iii) comparable monogamous countries (CMCs) that lie between 20° North and South latitudes (developing countries), and

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Table 1. Comparison of data from highly polygynous, less polygynous and comparable monogamous countries. In highly polygynous country, more than 10% married men have more than two wives. Adapted from Tertilt [63].

variables	highly polygynous countries	less polygynous African countries	comparative monogamous countries	North America/ Western Europe
no. of countries	28	20	58	24
female age at first marriage	19.9	22.7***	25.0***	29.6***
age gap (first wife only)	6.4	3.9***	2.8***	2.4***
total fertility	6.78	5.97**	4.62***	1.84***
child mortality rate, 1980 (%)	19.4	18.3	11.6**	1.4***
infant mortality rate, 1980 (%)	12.2	11.5	6.9**	1.2***
GDP *per capita*, 1985 (US$)	975	1574*	2798***	11 950***

*$p < 0.05$ (indicates comparison with highly polygynous countries).
**$p < 0.01$.
***$p < 0.001$.

(iv) North America and Western Europe, which provide a reference point. The HPCs are all African save for Bangladesh and Kuwait. The variables are mostly self-explanatory, though note that age gap gives the difference between the mean age of the husband or wife at their respective *first* marriages. In a polygynous society, the gap would further increase if the mean age for males included all subsequent wives [63,64].

HPCs have the lowest age of first marriage for females at 19.9 years, and the largest age gap between husbands and their first wife. The age of 19.9 years is significantly lower than in LPACs (at 22.7 years) and much lower than CMCs, where the mean age is 25. In HPCs, 36.7 per cent of women are married between the ages of 15 and 19. The age gap increases from 2.8 years in CMCs to 6.4 years in HPCs. In HPCs, the age gap goes as high as 9 years. Fertility drops from 6.78 in HPCs to 4.62 in CMCs. Similar patterns are obtained if one uses GDP *per capita* instead of latitude to create these categories [63].

These patterns are supported by other analyses. Using a country-level measure of the degree of polygyny, regression analyses also show that greater polygyny is associated with (i) lower ages at first marriage for females, (ii) larger spousal age gaps, and (iii) higher fertility rates, controlling for GDP [65]. The electronic supplementary material also reviews convergent findings derived from comparing monogamous and polygynous households within the same society.

(iii) *Implication: normative monogamy increases gross domestic product* per capita

Tertilt [63] constructed a decision model to investigate how marriage systems influence economic productivity and fertility. She assumes that men and women both care about having children and consuming other goods, but that men can continue to reproduce their entire lives, while women are limited to only a portion of their lives. She shows that this model produces polygynous mating patterns under a wide range of conditions, and that once calibrated, it generates predictions that qualitatively fit the empirical patterns of polygynous countries. Tertilt then uses the model calibrated to HPCs to investigate what would happen if monogamy were imposed on everyone. The model predicts that: (i) fertility rates go down, (ii) spousal age gaps shrink, (iii) saving rates increase, (iv) bride prices disappear, and (v) GDP *per capita* goes up substantially. The main cause of these effects is that men cannot invest in obtaining additional wives or selling daughters, so instead they have fewer children, invest in production, and both save and consume more. That is, the population looks less like a HPC and more like a CMC.

Interestingly, Tertilt [64] shows that imposing monogamy has a much bigger effect on GDP *per capita* than increasing the decision-making power of women. To explore this, Tertilt alters her model so that reproductive decisions are made by women instead of men, but permits polygyny. In this version of the model, the number of wives per husband declines a bit (monogamy does not emerge), as does fertility. GDP *per capita* increases and saving rates go up substantially, but the magnitudes of the effects are much smaller than the effects of imposing monogamy. This suggests that cultural group selection should act most directly on social norms that fortify monogamous marriage rather than directly on those that increase gender equality.

(b) *Normative monogamy reduces intra-household conflict*

Our reasoning predicts that increasing the extent and intensity of polygynous marriage will increase conflict within households because it (i) creates competition among co-wives, (ii) expands the spousal age gap, (iii) decreases the relatedness within households, and (iv) reduces paternity certainty (which increases male sexual jealousy). Allocations of household resources to another wife's children mean fewer resources for one's own children. Since co-wives are generally unrelated to each other and to each other's offspring, genetic relatedness does not provide the same degree of prophylaxis against intra-household violence as in monogamous households. Overall, lower mean

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relatedness and more unrelated pairs in polygynous households mean a greater threat of abuse, violence and homicide. By contrast, normative monogamy (i) eliminates conflict between co-wives, (ii) decreases child abuse, neglect and homicide by increasing the mean relatedness in households and reducing the number of unrelated adult–child dyads, and (iii) reduces spousal homicide and domestic abuse by decreasing the spousal age gap, male mate competition and paternity uncertainty, and by increasing the age of women's first marriage.

Co-wife conflict is ubiquitous in polygynous households. From anthropology, a review of ethnographic data from 69 non-sororal polygynous societies from around the globe [66] reveals no case where co-wife relations could be described as harmonious, and no hint that women's access to the means of production had any mitigating impact on conflict. Consistent with this, an in-depth study of a fundamentalist Mormon community in the US [67] found substantial conflict among co-wives. The electronic supplementary material provides more background and reviews additional evidence. From health psychology, a comprehensive review of psychological studies [68] concludes that children from polygamous families experience higher incidences of marital conflict, household violence and family disruptions than do children of monogamous families. This work also suggests that the creation of step-parents is more common as men often leave their first wives to be with their newer wives, but they keep the children, which opens the door for abuse and neglect by unrelated mothers.

Polygynous marriages also create elevated risks of intra-household abuse, neglect and homicide because such households have lower average relatedness, and more unrelated dyads. Each additional wife is unrelated to the existing co-wives, and to all of these wives' children. The number of unrelated dyads in such a household, in fact, increases with the square of the number of wives (see electronic supplementary material). Much empirical work in monogamous societies indicates that higher degrees of relatedness among household members are associated with lower rates of abuse, neglect and homicide [69,70]. Living in the same household with genetically unrelated adults is the *single biggest risk factor* for abuse, neglect and homicide of children. Stepmothers are 2.4 times more likely to kill their stepchildren [71] than birth mothers, and children living with an unrelated parent are between 15 and 77 times more likely to die 'accidentally' [72].

Converging with these ideas is long-term research in the Caribbean, which shows how different household compositions impact cortisol levels (a stress hormone) in children. Children in nuclear families with only genetic parents showed the lowest cortisol levels. By contrast, children in households with distant relatives, stepfathers and half-siblings showed the highest cortisol levels of any household composite in the sample [73]. This suggests that the children of polygynous households will run higher cortisol levels owing to the presence of unrelated mothers and half-siblings.

The above-described effects of relatedness emerge from work in monogamous societies, so one could argue that they are somehow not applicable to polygynous households. However, research among fundamentalist Mormon communities reveals that the effects of relatedness are evident within polygynous households: full siblings show greater association, effect, solidarity and altruism when compared with half-siblings in the same household [74].

Finally, as explained above, normative monogamy may reduce spousal homicide, domestic violence and the use of physical coercion by decreasing the spousal age gap, gender inequality, paternal uncertainty and mate competition. Research indicates that both spousal age gaps and paternity uncertainty are important predictors of spousal homicides [75]. Meanwhile, cross-national regressions reveal that stronger monogamous marriage norms are associated with less (i) domestic violence, (ii) maternal mortality, (iii) female genital mutilation, and (iv) sex trafficking, even after controlling for GDP [65]. The electronic supplementary material expands these points.

Before proceeding, we emphasize that it is not entirely clear that reducing the spousal age gap, intra-household conflict or gender inequality will increase success in inter-group competition. However, here are three reasons to suspect that this might be the case. First, later marriage and less conflict means a greater fraction of children in a society will be reared by older, more skilled mothers who have had more time to acquire experience and education. These women will have more influence in household decisions and thus have fewer children. These factors can create group advantages in socioecologies in which greater parental investment improves cognitive abilities or skills, increases trust, or instantiates patience. Second, the lower childhood mortality and better health outcomes created by greater parental investment implies that resources are not 'wasted' on children who never become productive adults. Third, in addition to fully harnessing the economically productive talents of women, reducing gender inequality may suppress the tendency for polygynous societies to culturally evolve norms and institutions aimed at controlling women, such as arranged marriage, female circumcision, purdah (seclusion of women) and brideprice [76], many of which appear costly at the societal level. However, even if reduced gender inequality and household conflict spread merely as by-products of cultural group selection operating to reduce crime rates (to increase trade and reduce transaction costs), they still provide predictions to test the more general theory.

(i) *Monogamous marriage increases paternal investment and improves childhood outcomes*

Increasing polygynous marriages decreases overall male parental investment by (i) eliminating opportunities for low-status males to establish pair-bonds (and invest in offspring), (ii) diluting the per-child investment in larger families, and (iii) shifting investment by high-status males from offspring into obtaining more long-term mates. While allowing the resources of richer men to be distributed among more children, the net effect of polygyny on male parental investment will often be to reduce the average investment

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per child. Normative monogamy provides increased opportunities for low-status males to marry, save and invest for the long term. The labour and talents of these would-be risk-taking criminals (and/or substance abusers) are instead channelled into long-term investments in family and child-rearing (reliable economic productivity). Their pair-bonding and paternal investment psychologies are tapped and harnessed relatively more than their risky, status-seeking mindsets. For married high-status males, normative monogamy raises the cost of seeking additional mates and thereby shifts efforts from mate-seeking to improving offspring quality.

We lack direct evidence for the effect of monogamous marriage on paternal investment, though ethnographic accounts suggest, for example, that highly polygynous fathers do not even know all of their children's names [77]. Nevertheless, both cross-cultural and historical evidence do indicate that the children of polygynous households have worse health outcomes compared with those in monogamous households, even after controlling for wealth, income and other demographic differences. We suspect that part of this difference results from the increased paternal investment in monogamous families, though it may also arise from the associations of monogamy with lower rates of household conflict, maternal mortality [65] or psycho-social stress (see the electronic supplementary material).

In Africa, diverse studies show that, relative to children from monogamous households, children from polygynous household risk diminished nutritional status, poorer health outcomes and elevated mortality. Table 1 shows that both infant and child mortality in HPCs are roughly twice that of CMCs. Much work supports this view [78–81]. Using data from 22 sub-Saharan African countries, Omariba & Boyle [80] found that children in polygynous families were 24.4 per cent more likely to die compared with children in monogamous families. Similarly, a study of six West African countries found that infants in polygynous families had a substantially greater risk of dying compared with children in monogamous households [82]. Community-level studies in Tanzania and Chad found that children in polygynous households had poorer nutrition than their counterparts in monogamous households from the same communities [83–85]. See electronic supplementary material for details.

Similar effects occur in North America. Using data from nineteenth century Mormons, Heath & Hadley [25] compare data from 90 households consisting of 45 headed by wealthy men (top 2% of wealth in that community) and 45 headed by poor married men (from the bottom 16%). These data show that wealthy males had on average 3.2 wives compared to 1.4 among the poor. All but five of the wealthy men had more than one wife. One rich man had 11 wives. Overall, the wealthy men controlled 120 women while the poor controlled 63. This means that 90 husbands had 183 wives, which implies roughly 93 missing men had no wives. While wealthy men had more total offspring and longer reproductive careers (33 years for wealthy men compared to 22 for poor men), the children of poor men had better survival rates for their children to age 15. For poor men, 6.9 of their offspring (per wife) survived on average to age 15, while for wealthy men only 5.5 of their offspring (per wife) survived to age 15. This is amazing, given that the poor men had less than 10 per cent of the wealth of the rich men, and the rich men had significantly more total offspring (including those that did not make it to 15). Perhaps, most telling is a comparison of rich with poor men, both with one or two wives: poor men's children out-survived rich men's 6.9 to 5.7 (mean number of offspring surviving to age 15 per wife). This supports the idea that poor men with insufficient resources for another wife tend to invest more in their existing offspring while rich men with the same number of wives invest less in offspring because they are expending resources seeking additional wives (see electronic supplementary material).

4. DISCUSSION

We propose that the unusual package of norms and institutions that constitute modern monogamous marriage systems spread across Europe, and then the globe, because of the package's impact on the competitive success of the polities, nations and religions that adopted this cultural package. Reducing the pool of unmarried men and levelling the reproductive playing field would have decreased crime, which would have spurred commerce, travel and the free flow of ideas and innovations. Greater security would have reduced transaction costs and both public and private security expenditures. Instead of engaging in risky status-seeking endeavours, low-status males would be more likely to marry, thus becoming risk-averse and future-oriented, and focus on providing for their offspring in the long run. Higher status males, instead of seeking to attract additional wives, would make long-term investments and attend to their offsprings' security. More personal security and less crime would have meant that many more individuals could shift to investing in long-term payoffs, including businesses, apprenticeships and education. Reduced demand for brides would have increased the age of first marriage for women and gender equality, which would have reduced total fertility. These expectations are broadly consistent with historical patterns in pre-modern England during the lead up to the industrial revolution [86].

The conditions in which inter-group competition favours normative monogamy are probably limited to situations involving competition among very complex human societies: those with substantial divisions of labour, well-developed commerce, inter-community trade, standing armies and highly skilled occupations. Competition among less complex societies need not favour normative monogamy. Some circumstances, such as those in which subsistence economies are dominated by female or child labour, would appear to favour greater polygynous marriage. When inter-group competition relies on large numbers of motivated young men to engage in continuous raiding and warfare to obtain resources, slaves, territory and concubines, groups with greater polygyny may generate larger and more motivated pools of males for these risky activities. If these larger pools of men more effectively expand their territories, populations and resources at the expense of

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groups that constrain this pool, cultural group selection could favour greater polygyny. Supporting ethnographic cases are numerous [46,87], and cross-cultural analyses confirm several of the above proposed associations [44].

Religion may also be important in the spread of normative monogamy. The infusion of norms related to monogamous marriage into the supernaturally reinforced set of beliefs propounded by Christianity [88] may have been crucial to the long-term success of this marriage system and one element in the set of effects on religion created by cultural group selection [89]. The central challenge to monogamous marriage norms comes from wealthy and politically powerful men who have substantial fitness-related motivations and incentives to resist such practices. Imbuing monogamy with supernatural sanction, including the ability to create legitimate, divinely recognized, heirs in hereditary monarchies may have made all the difference in the pre-industrial world.

More generally, it is important to realize that the evolutionary processes we have highlighted should be thought of as favouring cultural practices that are 'polygyny-inhibiting', with prescriptive monogamy at the extreme. Islam, for example, contains polygyny-inhibiting elements [90] that attempt to constrain men's ability to accumulate wives by (i) placing an upper limit of four wives, (ii) requiring men to deal justly with all of their wives, and (iii) permitting a potential bride to contractually stipulate that her marriage becomes invalid if her husband marries again.

Other economic and evolutionary approaches posit that monogamous marriage arises from some form of fitness- [17] or utility-maximizing [18] decision. Such models are useful if they help us understand how cultural evolution could shape sets of inter-related social norms and institutions. There is little doubt that norms about spousal number, for example, coevolve with norms regarding inheritance, transfer payments and sexual fidelity. However, as the electronic supplementary material explains, such non-cultural approaches fail to account for (i) the normative nature of marriage systems (third-party condemnation of norm violators), (ii) the broad historical patterns in the expansion of monogamous marriage, (iii) the lack of polygynous marriage among wealthy North Americans, or (iv) the persistent challenges that nation states face in suppressing the spread of polygynous communities. Moreover, such accounts would have to assume that the empirical patterns we reviewed above are mere epiphenomena, which did not impact cultural evolution.

In closing, it is worth speculating that the spread of normative monogamy, which represents a form of egalitarianism, may have helped create the conditions for the emergence of democracy and political equality at all levels of government [7,91]. Within the anthropological record, there is a statistical linkage between democratic institutions and normative monogamy [92]. Pushing this point, these authors argue that dissipating the pool of unmarried males weakens despots, as it reduces their ability to find soldiers or henchman. Reduced crime would also weaken despots' claims to be all that stands between ordinary citizens and chaos. Historically, we know that universal monogamous marriage preceded the emergence of democratic institutions in Europe, and the rise of notions of equality between the sexes (see our historical sketch in the electronic supplementary material). In Ancient Greece, we do not know which came first but we do know that Athens, for example, had both elements of monogamous marriage and of democracy. In the modern world, analyses of cross-national data reveal positive statistical relationships between the strength of normative monogamy with both democratic rights and civil liberties [65]. In this sense, the peculiar institutions of monogamous marriage may help explain why democratic ideals and notions of equality and human rights first emerged in the West [6].

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