# “Beyond Twins”

Lindon Eaves,
VIPBG, Richmond
Boulder CO,
March 2012

# The Twin Tool-Kit

- Continuous and categorical data
- Twins
- Univariate and Multivariate ACE
- Developmental Change
- Heterogeneity/Moderation
- Definition variables

THIS IS JUST A TOOL KIT TO GET STARTED

# This week we have pretty much ignored

- Assortative Mating
- Explicit Specification of the Family Environment (e.g. enviromental effects of parental genotype)
- Genotype-environment covariance (e.g. “passive” rGE)
- Causal pathways between measures
- Some aspects of development

# The chances are…

…that your real questions don't fit into this basic framework

**BE CREATIVE…**
**IMAGINE…**

If you can write the model…

…you can fit it

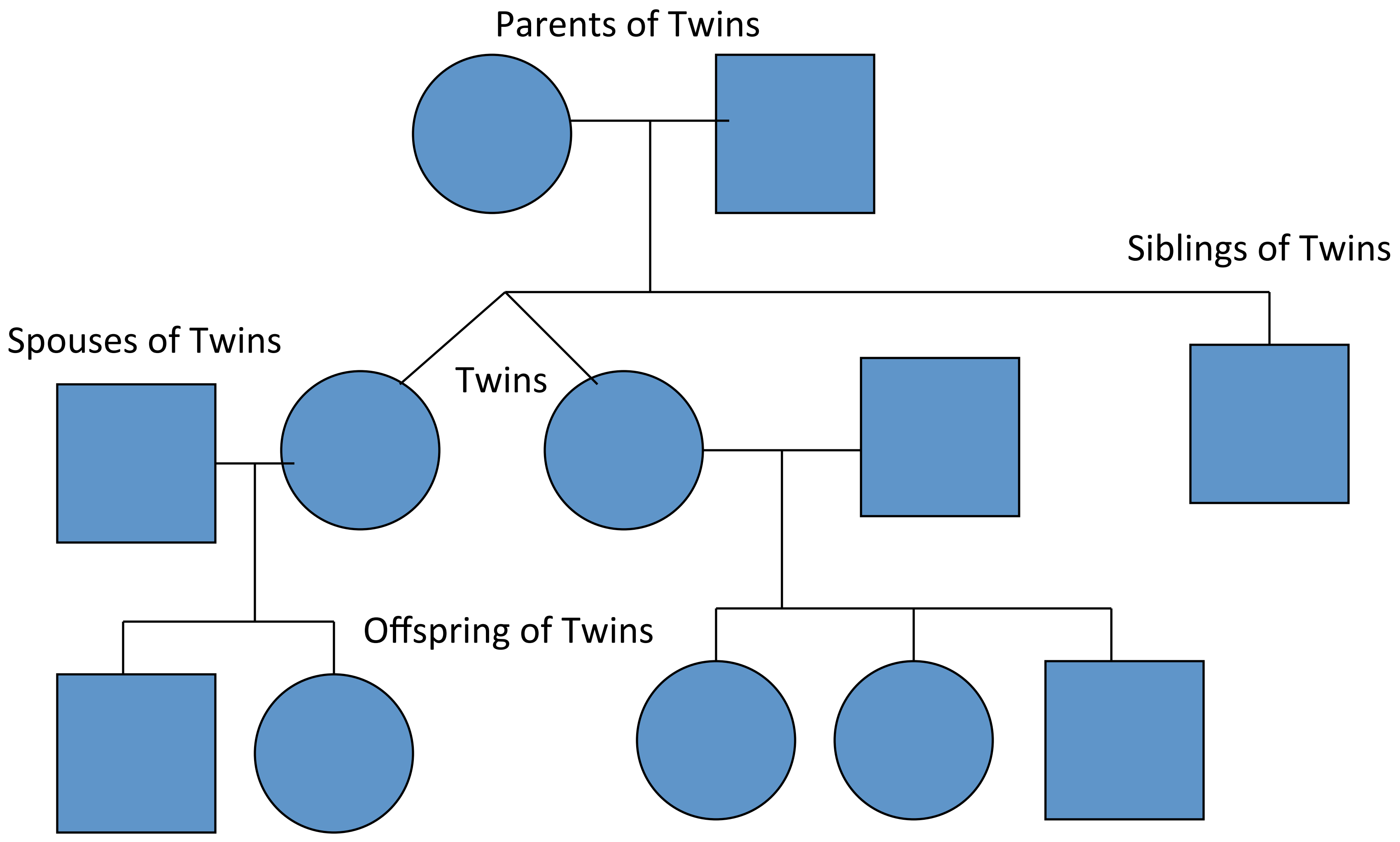
(If you can get the data)

Choose the design and write the model to reflect your own scientific questions

You can combine different elements to answer your question

Here are a few examples but they do not exhaust the possibilities

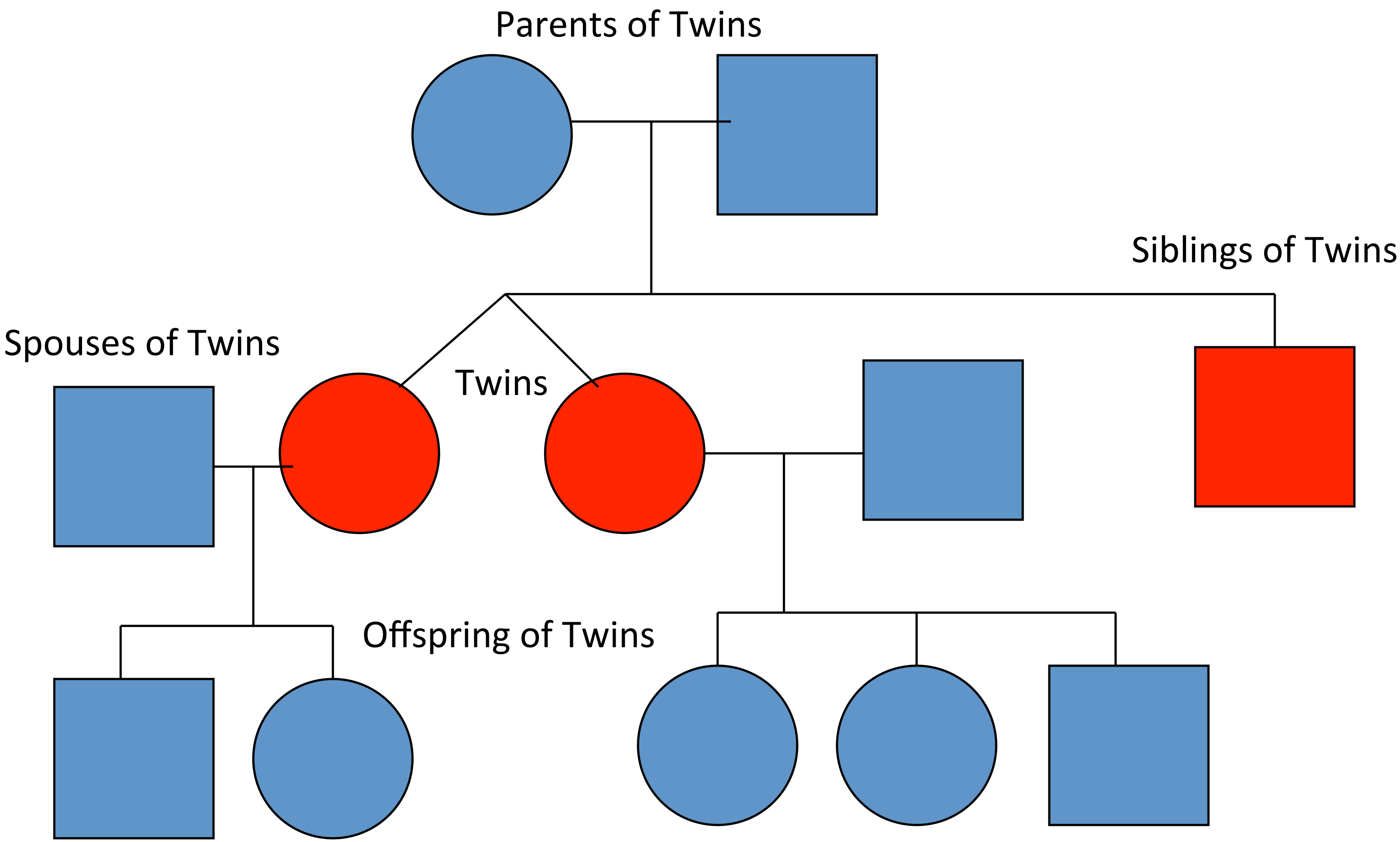
# Extended Kinships of Twins



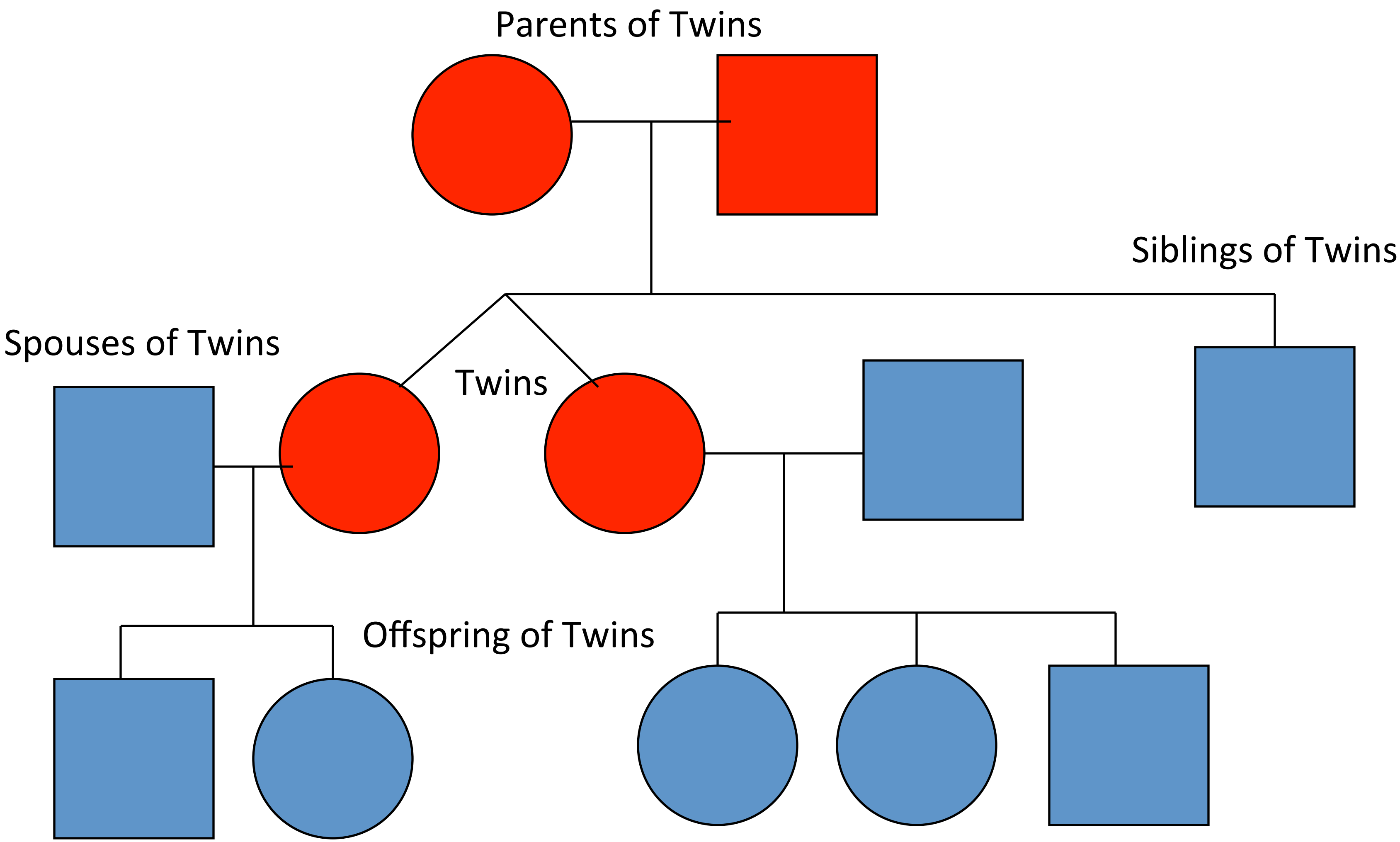
# Can Extend Pedigrees by Using Reports by Relatives

BUT NEED TO BE CAREFUL ABOUT RATER BIASES

# Twins and Siblings



# Twins and Parents ("TAP")



# Transmission of Attitudes Toward Abortion and Gay Rights: Effects of Genes, Social Learning and Mate Selection

**Lindon J. Eaves · Peter K. Hatemi**

Behav Genet. 2008 May;38(3):247-56.

**Table 2** Polychoric correlations for attitudes to abortion and gay rights

| Relationship | Correlation | | N (pairs) |
|---|---|---|---|
| | Abortion | Gay rights | |
| Husband–wife | 0.632 | 0.581 | 5162 |
| Mother–daughter | 0.500 | 0.469 | 4802 |
| Mother–son | 0.373 | 0.391 | 3233 |
| Father–daughter | 0.428 | 0.365 | 3166 |
| Father–son | 0.398 | 0.389 | 2315 |
| Male siblings | 0.420 | 0.309 | 1564 |
| Female siblings | 0.463 | 0.453 | 3701 |
| Unlike-sex siblings | 0.405 | 0.346 | 4462 |
| Male DZ twins | 0.423 | 0.371 | 610 |
| Female DZ twins | 0.557 | 0.491 | 1273 |
| Unlike-sex DZ twins | 0.425 | 0.393 | 1397 |
| Male MZ twins | 0.553 | 0.574 | 814 |
| Female MZ twins | 0.676 | 0.599 | 1982 |
| Retest male | 0.801 | 0.774 | 1019 |
| Retest female | 0.864 | 0.806 | 2912 |

# Path model for biological and cultural inheritance

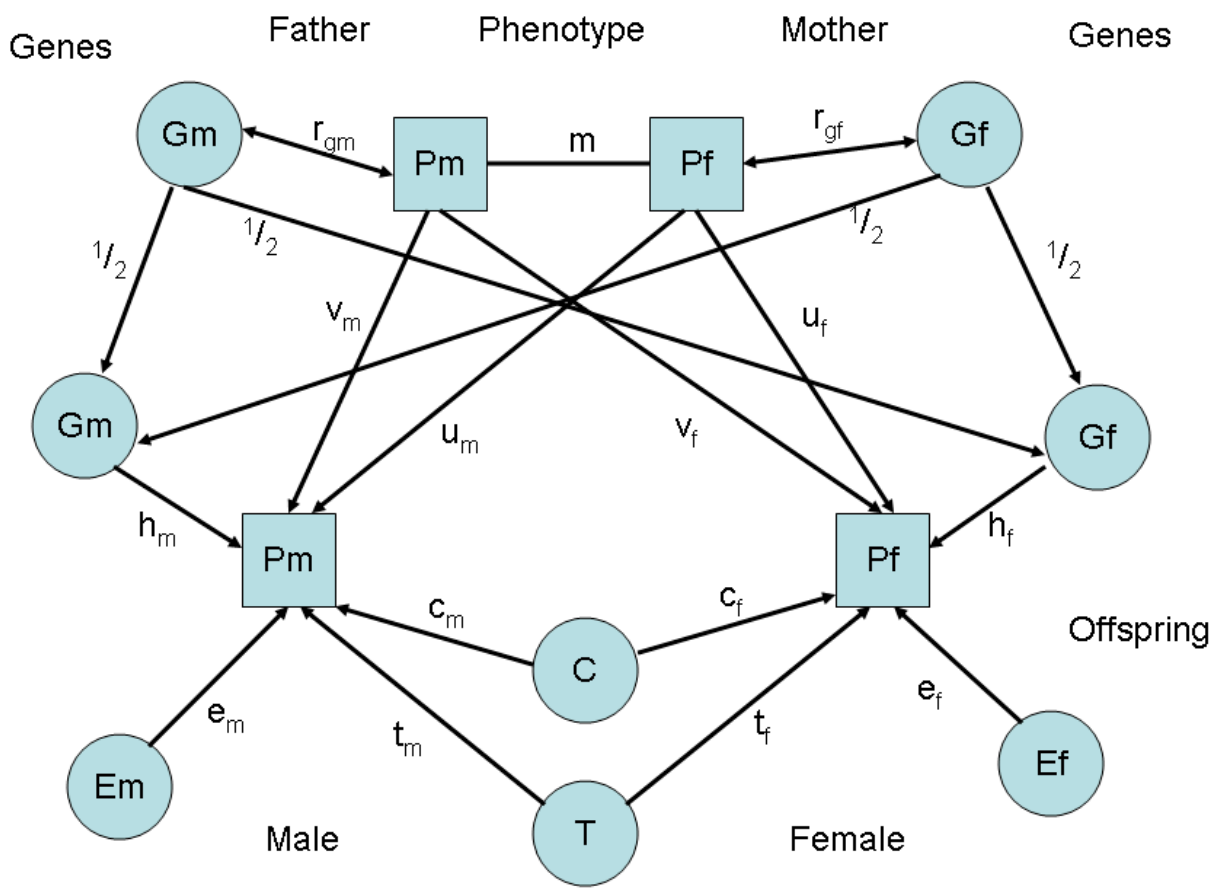


**Table 4: Estimates of path coefficients**

| Parameter | Abortion | Gay Rights | Path |
|---|---|---|---|
| $h_m$ | 0.756 | 0.834 | Additive genetic effects to male phenotype |
| $h_f$ | 0.716 | 0.710 | Additive genetic effects to female phenotype |
| $h_s$ | 0 | 0 | Sex-specific genetic effects |
| $c_m$ | 0.370 | 0.051 | Non-transmitted shared environment to male siblings |
| $c_f$ | 0.255 | 0.341 | Non-transmitted shared environment to female siblings |
| $t_m$ | 0.048 | 0.301 | Additional twin shared environment (males) |
| $t_f$ | 0.355 | 0.203 | Additional twin shared environment (females) |
| $u_f$ | 0.184 | 0.261 | Mother-daughter cultural inheritance |
| $u_m$ | -0.140 | -0.033 | Mother-son cultural inheritance |
| $v_f$ | -0.100 | -0.203 | Father-daughter cultural inheritance |
| $v_m$ | 0.107 | -0.040 | Father-son cultural inheritance |
| m | 0.761 | 0.734 | Phenotypic correlation between spouses |
| $r_{gm}$ | 0.895 | 0.881 | Reliability (male) |
| $r_{gf}$ | 0.929 | 0.898 | Reliability (female) |

Note: "reliabilities" are estimated as the path from "true" score to observed score. Test-retest correlations are the squares of the path coefficients.

**Table 5: Proportions of reliable variation explained by sources of variance (full model)**

| | Proportion of reliable variance | | | |
|---|---|---|---|---|
| | Abortion | | Gay Rights | |
| **Component of variance** | Males | Females | Males | Female |
| Additive genetic | 0.572 | 0.513 | 0.696 | 0.505 |
| Non-shared environment | 0.316 | 0.213 | 0.288 | 0.253 |
| Shared sibling environment | 0.137 | 0.065 | 0.003 | 0.116 |
| Extra-shared twin environment | 0.002 | 0.112 | 0.091 | 0.041 |
| Vertical cultural inheritance | 0.008 | 0.016 | 0.005 | 0.031 |
| Genotype-environment covariance | -0.035 | 0.080 | -0.081 | 0.053 |
| Total shared environment | 0.147 | 0.193 | 0.099 | 0.188 |
| Reliability (retest) | 0.801 | 0.863 | 0.776 | 0.806 |

**The mediating effect of parental neglect on adolescent and young adult anti-sociality: A longitudinal study of twins and their parents (LTAP).**

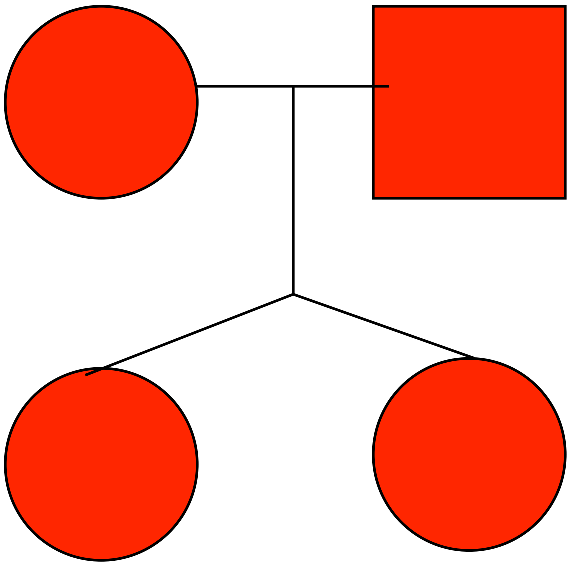
**Running title: Childhood adversity and anti-social behavior.**

Lindon J Eaves, Elizabeth C Prom, Judy L Silberg

Behav Genet. 2010 Jul;40(4):425-37.

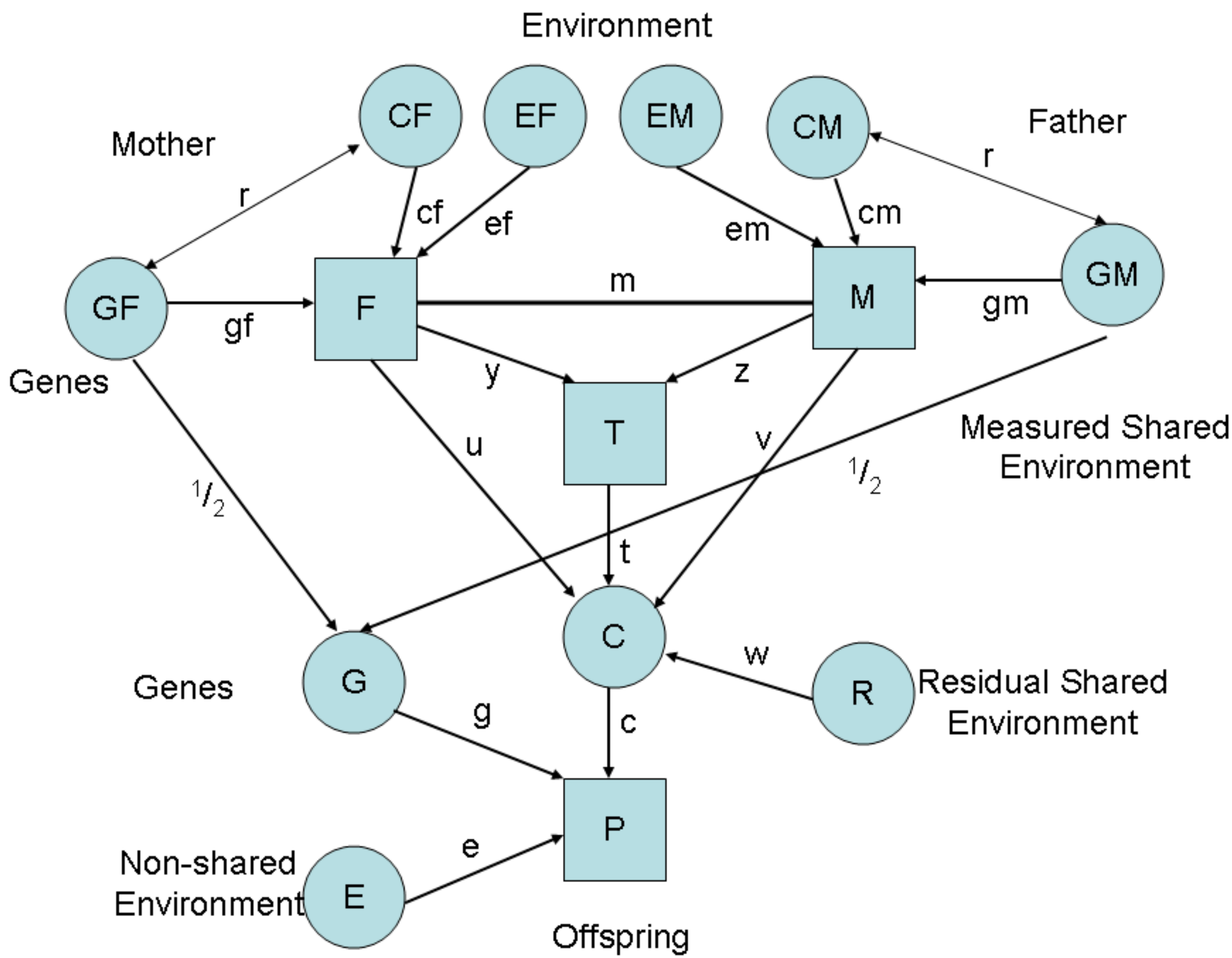
Twins and Parents ("TAP")

ADULTS



TWINS MEASURED
AS JUVENILES AND ADULTS

Conceptual model for the effects of genes and the family environment on anti-social behavior.



## Polychoric correlations between childhood adversity and anti-social behavior of adult and juvenile offspring

| Outcome | Statistic | | |
|---|---|---|---|
| | N | r | a.s.e. |
| Adult male | 476 | 0.1506 | 0.0770 |
| Adult female | 513 | 0.2986 | 0.0659 |
| Juvenile male | 364 | 0.2276 | 0.1045 |
| Juvenile female | 406 | 0.3183 | 0.0824 |

## Polychoric correlations between parental (adult) anti-social behavior (ASP) and childhood adversity

| Relationship | Statistic | | |
|---|---|---|---|
| | N | R | a.s.e. |
| Mother-Father ASP | 942 | 0.4006 | 0.0370 |
| Father ASP-Adversity | 489 | 0.2805 | 0.0707 |
| Mother ASP.-Adversity | 577 | 0.4121 | 0.0565 |

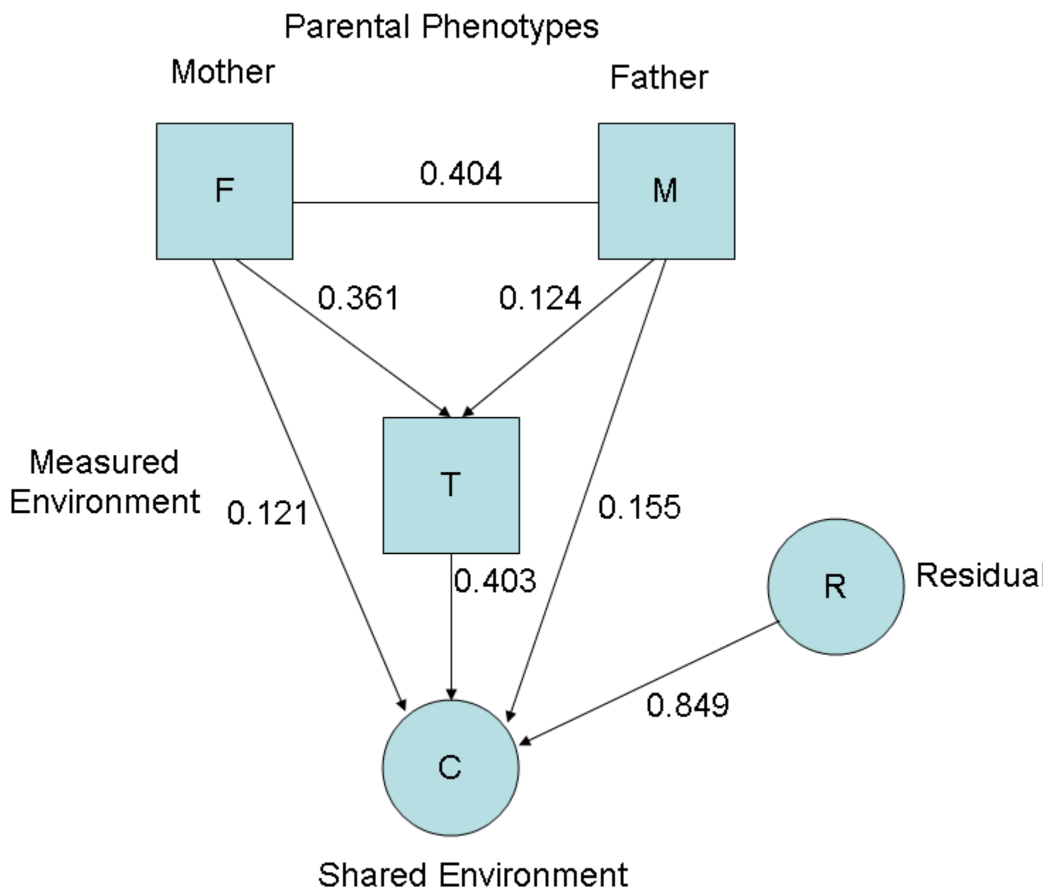
Polychoric correlations between anti-social behavior of (adult) parents adult (ASP) and juvenile (CD) anti-social behavior of their offspring.

| Relationship | Statistic | | |
| --- | --- | --- | --- |
| | N | r | a.s.e. |
| Mother-adult son | 977 | 0.2368 | 0.0398 |
| Mother-adult daughter | 1158 | 0.2126 | 0.0380 |
| Mother-juvenile son | 662 | 0.1475 | 0.0583 |
| Mother-juvenile daughter | 746 | 0.2454 | 0.0558 |
| Father-adult son | 761 | 0.1507 | 0.0471 |
| Father-adult daughter | 869 | 0.2558 | 0.0442 |
| Father-juvenile son | 525 | 0.2035 | 0.0671 |
| Father-juvenile daughter | 568 | 0.1450 | 0.0681 |

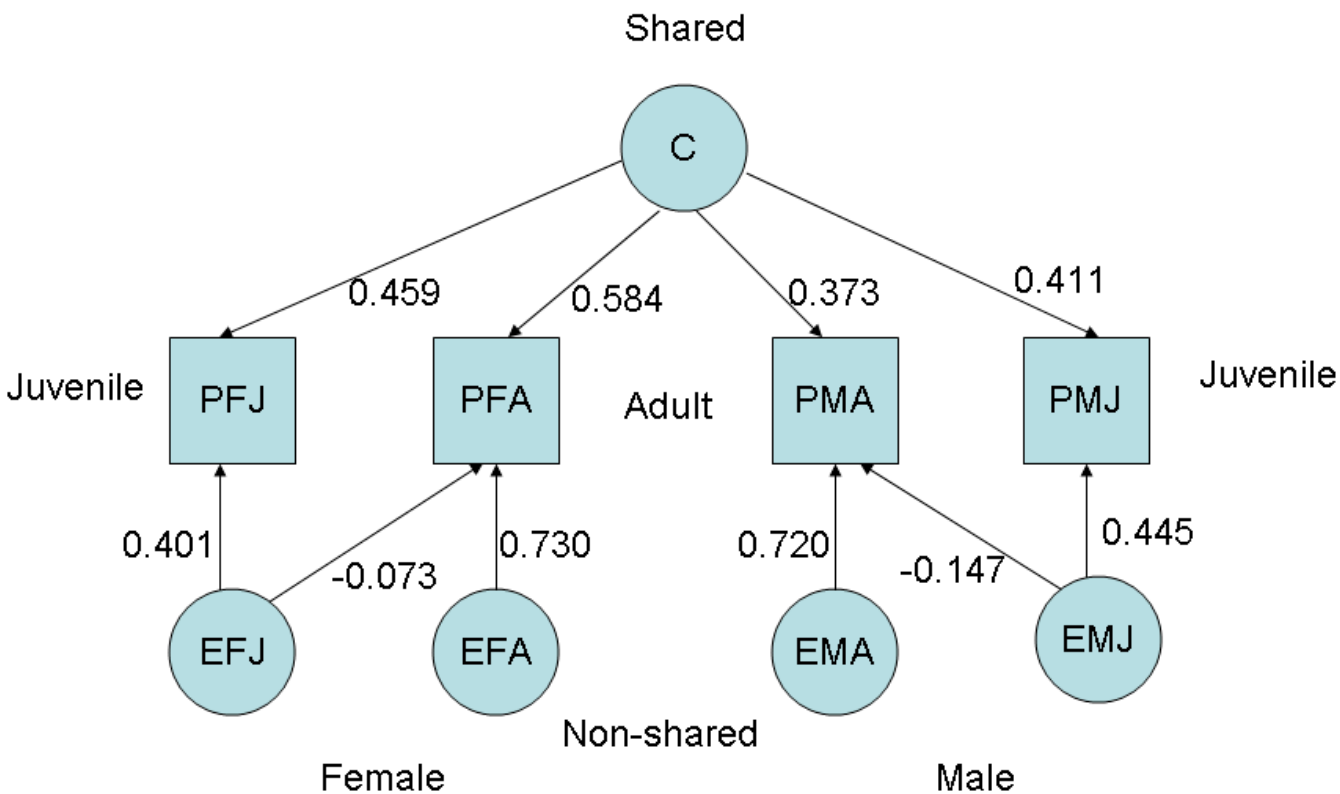
# Polychoric correlations for juvenile conduct disorder and adult anti-social personality in YAFU/VTSABD twins.

| Relationship | | Statistic | | |
|---|---|---|---|---|
| | | N | r | a.s.e. |
| Twins (as adults) | MZm | 243 | 0.5654 | 0.0615 |
| | MZf | 333 | 0.5093 | 0.0611 |
| | DZm | 137 | 0.2646 | 0.1078 |
| | DZf | 154 | 0.4069 | 0.0960 |
| | DZmf | 209 | 0.3069 | 0.0875 |
| Twins (as juveniles) | MZm | 169 | 0.8003 | 0.0572 |
| | MZf | 225 | 0.8023 | 0.0552 |
| | DZm | 101 | 0.5153 | 0.1498 |
| | DZf | 92 | 0.4189 | 0.1565 |
| | DZmf | 132 | 0.0150 | 0.1809 |
| Twins (adult-juvenile) | MZm | 288 | 0.1751 | 0.0879 |
| | MZf | 394 | 0.1126 | 0.0848 |
| | DZm | 168 | 0.1526 | 0.1284 |
| | DZf | 164 | 0.3596 | 0.1101 |
| | DZmf | 115 | 0.0595 | 0.1474 |
| | DZfm | 113 | 0.0647 | 0.1630 |
| Within subject (adult-juvenile) | Males | 569 | 0.2452 | 0.0632 |
| | Females | 674 | 0.1103 | 0.0643 |

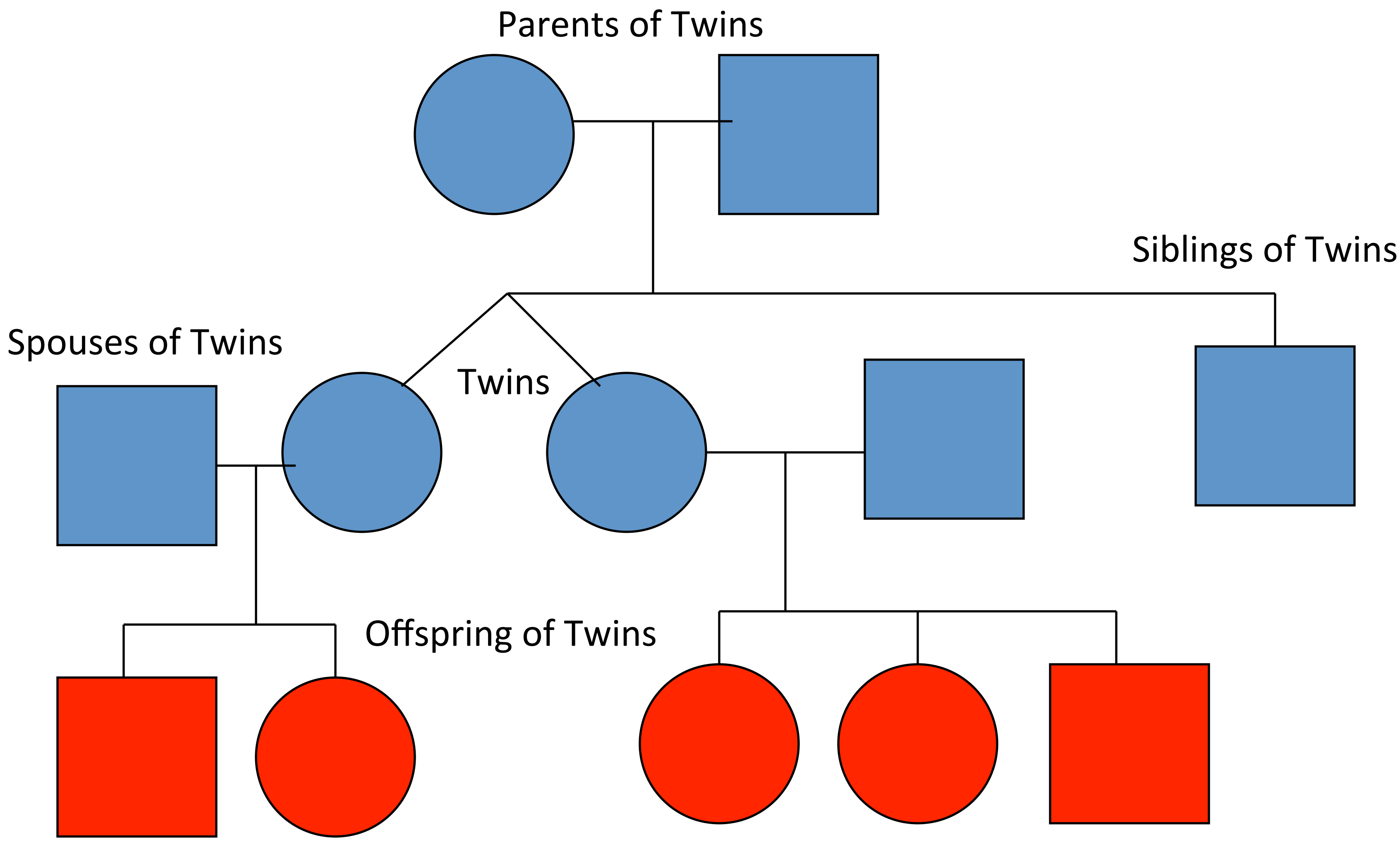
# Estimated contributions of parents and residual effects to the shared environment of twin offspring.



# Effects of the unique and shared environment on adult and juvenile anti-social behavior and females.



# Children of Twins ("COT")



# Gestational Age

## Racial Differences in Genetic and Environmental Risk to Preterm Birth

Timothy P. York, Jerome F. Strauss,
Michael C. Neale, Lindon J. Eaves

PLoS One. 2010 Aug 25;5(8):e12391.

Table 2. Sample frequencies by parental relationship and race.

| Parental relationship | European American | | African American | |
|---|---|---|---|---|
| | **N. Families** | **N. Births** | **N. Families** | **N. Births** |
| Sibship | 284,446 | 575,709 | 66,983 | 119,791 |
| Maternal half-sibship | 6,736 | 12,269 | 2,431 | 4,515 |
| Paternal half-sibship | 5,419 | 9,800 | 2,839 | 5,292 |
| MZ male twin | 595 | 1,092 | 69 | 99 |
| MZ female twin | 618 | 1,212 | 98 | 144 |
| DZ male twin | 393 | 700 | 52 | 77 |
| DZ female twin | 368 | 696 | 72 | 119 |
| DZ male-female twin | 936 | 1,614 | 139 | 210 |
| *Total* | 299,511 | 603,092 | 72,683 | 130,247 |

Table 1. Expected covariance of gestational age expressed as variance components between pregnancy outcomes as a function of relationship between offspring.

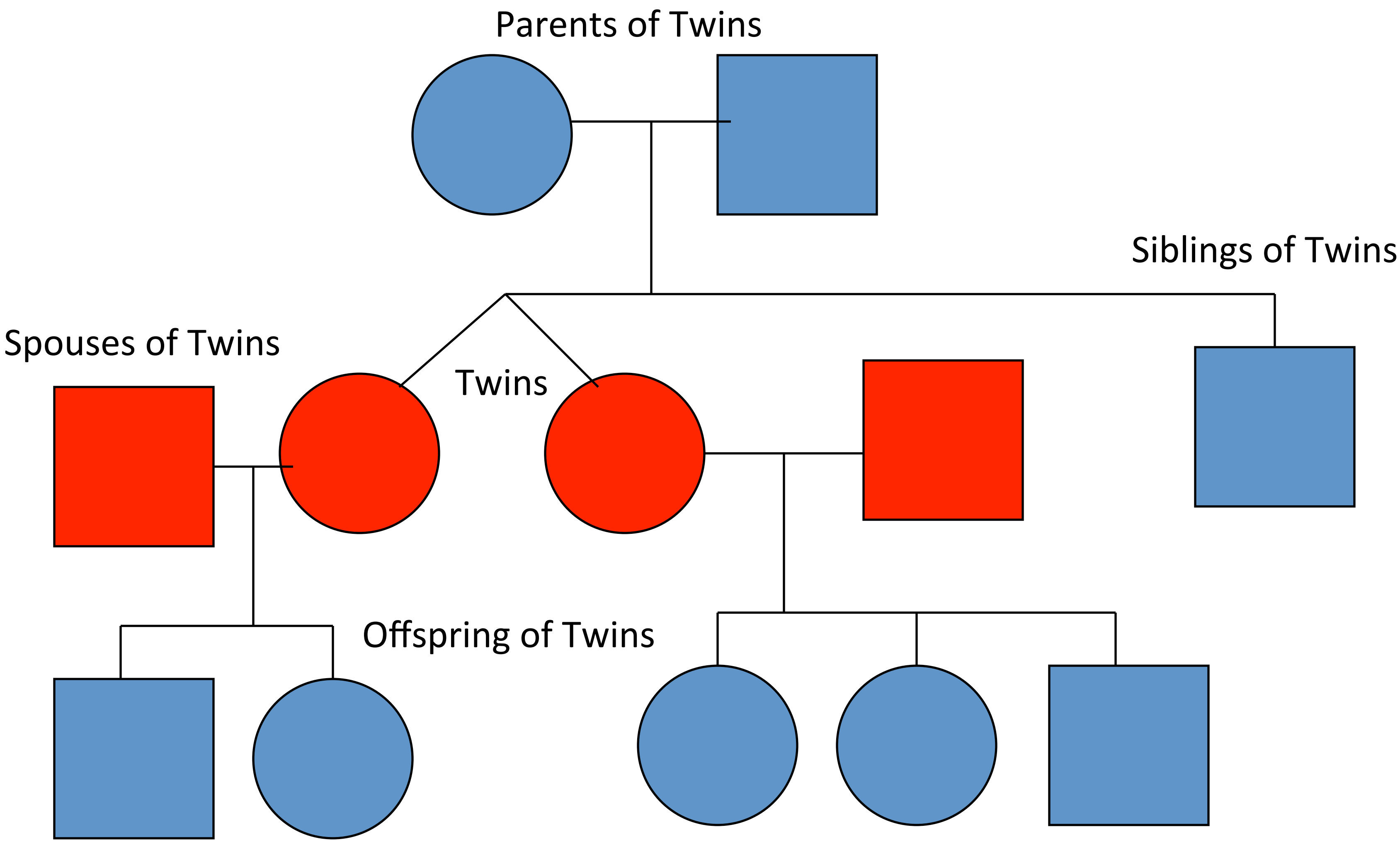
| **Parental relationship** | **Fetal relationship** | **Expected covariance** |
|---|---|---|
| MZ female twins | Half-sibling | $\frac{1}{4} f^2 + m^2$ |
| DZ female twins | Cousin | $\frac{1}{8} f^2 + \frac{1}{2} m^2$ |
| MZ male twins | Half-sibling | $\frac{1}{4} f^2$ |
| DZ male twins | Cousin | $\frac{1}{8} f^2$ |
| DZ male-female twins | Cousin | $\frac{1}{8} f^2$ |
| Sibship | Sibling | $\frac{1}{2} f^2 + m^2 + c^2$ |
| Maternal half-sibship | Half-sibling | $\frac{1}{4} f^2 + m^2 + hc^2$ |
| Paternal half-sibship | Half-sibling | $\frac{1}{4} f^2 + hc^2$ |

$f^2$ =fetal genetic, $m^2$ =maternal genetic, $c^2$ =shared familial environment
$h$ = parameter to allow for differences in half-sibling versus full-sibling shared environment ("fudge factor")

Table 4. Estimated variance components from model 2 with empirically derived 95% bootstrap confidence intervals adjusted for covariates (birth order, maternal age, fetal sex, source of care, smoking, maternal education).

| | Full Genetic Model (Model 2) | | | Reduced Genetic Model (Model 8) | | |
|---|---|---|---|---|---|---|
| **Source** | **Estimate** | **95% CI** | **Percentage** | **Estimate** | **95% CI** | **Percentage** |
| *African American* | | | | | | |
| Fetal genetic | 0.264 | (0.0, 2.302) | 3.7 | - | - | - |
| Maternal genetic | 0.976 | (0.274, 1.357) | 13.8 | 1.040 | (0.531, 1.445) | 14.7 |
| Shared environment | 1.215 | (0.499, 1.666) | 17.1 | 1.281 | (0.872, 1.781) | 18.0 |
| Unique environment | 4.642 | (3.559, 4.899) | 65.4 | 4.777 | (4.625, 4.927) | 67.3 |
| *European American* | | | | | | |
| Fetal genetic | 1.325 | (0.640, 1.927) | 35.2 | 1.325 | (0.695, 1.964) | 35.2 |
| Maternal genetic | 0.503 | (0.263, 0.767) | 13.4 | 0.503 | (0.235, 0.758) | 13.4 |
| Shared environment | 0.263 | (0.006, 0.537) | 7.0 | 0.264 | (0.027, 0.537) | 7.0 |
| Unique environment | 1.673 | (1.355, 2.024) | 44.4 | 1.674 | (1.355, 1.990) | 44.5 |

# Spouses of Twins ("SPOT")

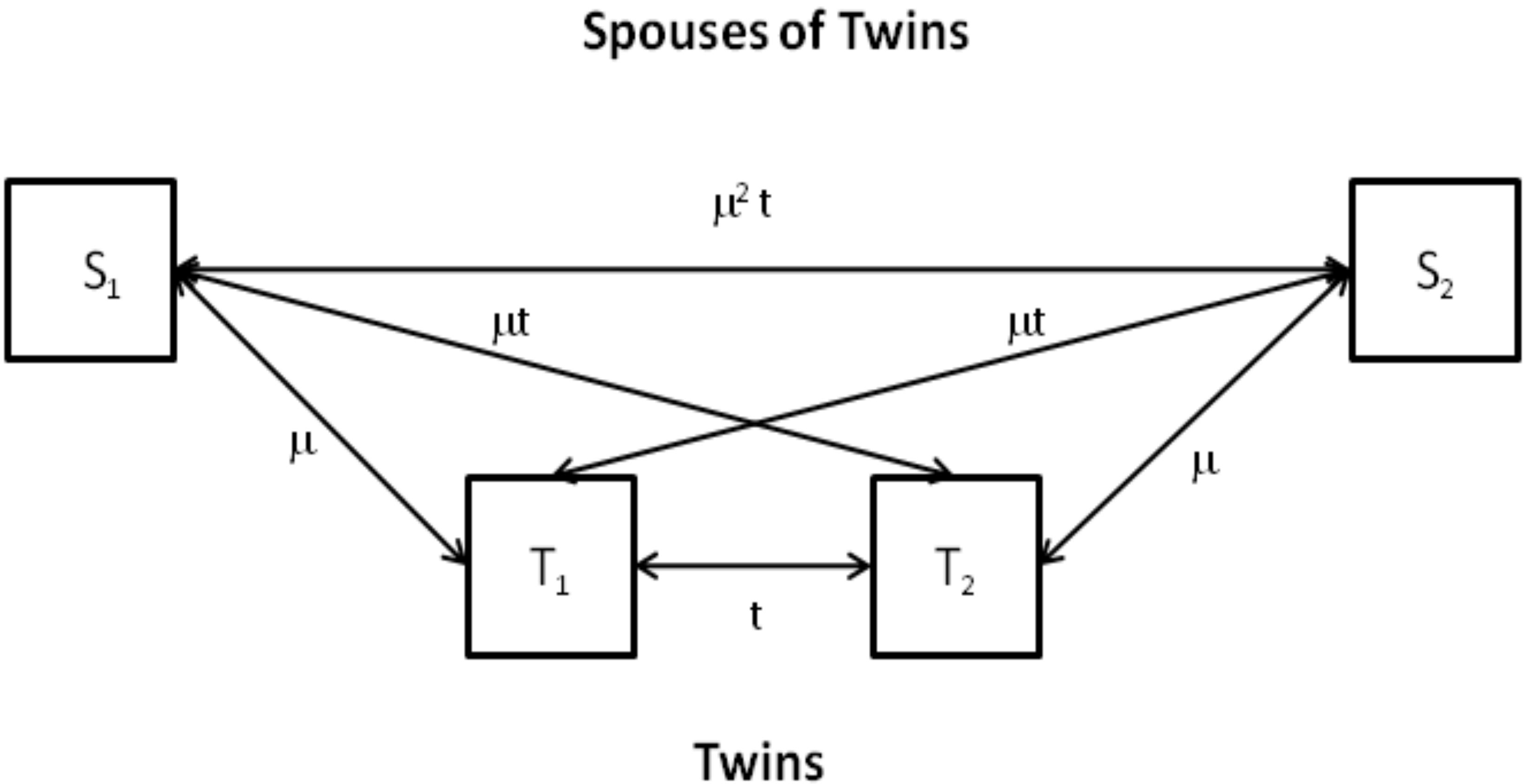


# Modeling the Cultural and Biological Inheritance of Social and Political Behavior in Twins and Nuclear Families

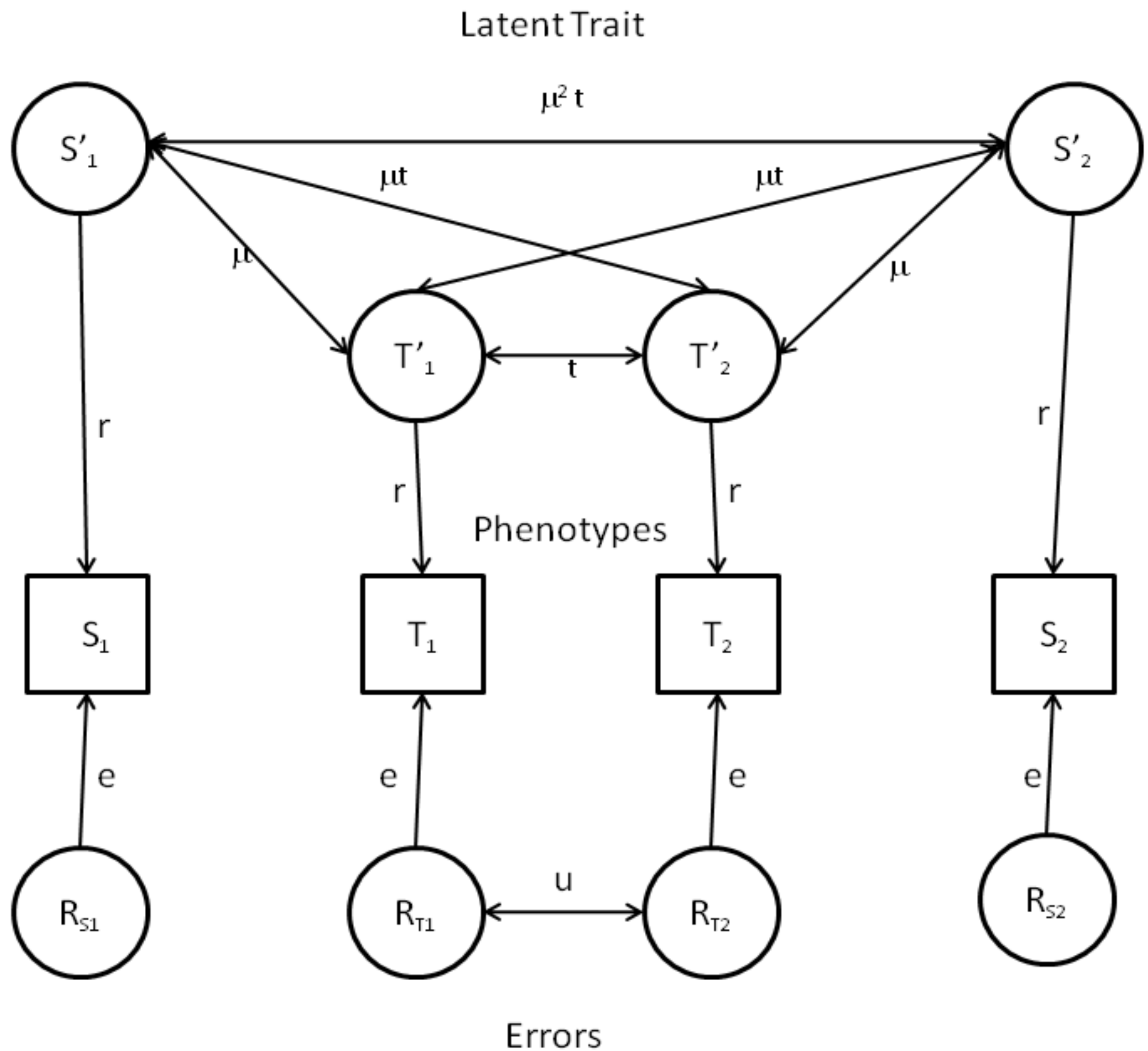
**Lindon J. Eaves, Peter K. Hatemi,**
**Andrew C. Heath, Nicholas G. Martin**

***In P.Hatemi and R.McDermott (2011) "Man is by Nature a Political Animal", Chicago, IL: University of Chicago Press.***

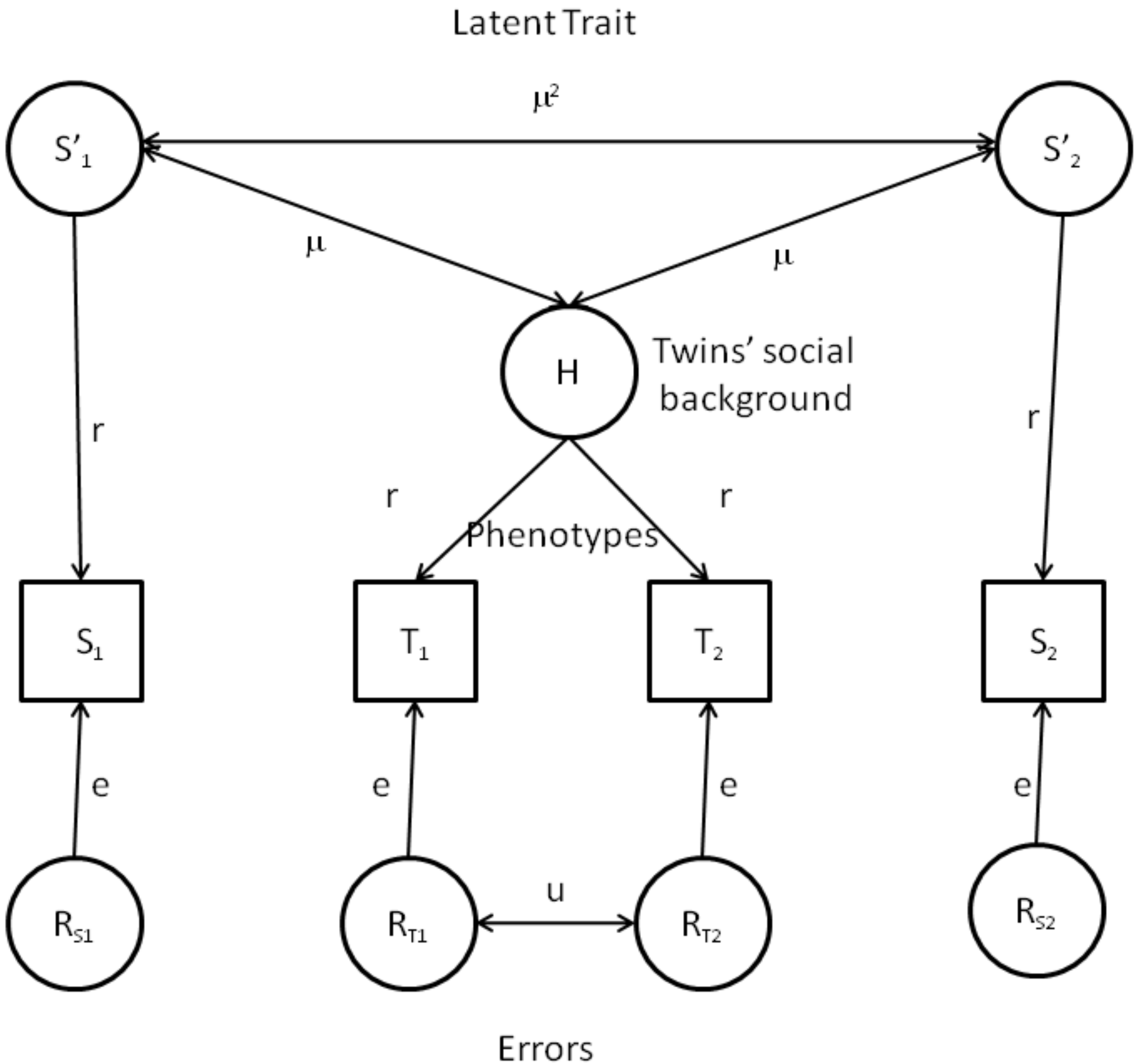
# Phenotypic Assortment



# Latent Variable Assortment (Phenotype subject to error)



# “Social Homogamy”



# Spousal Interaction

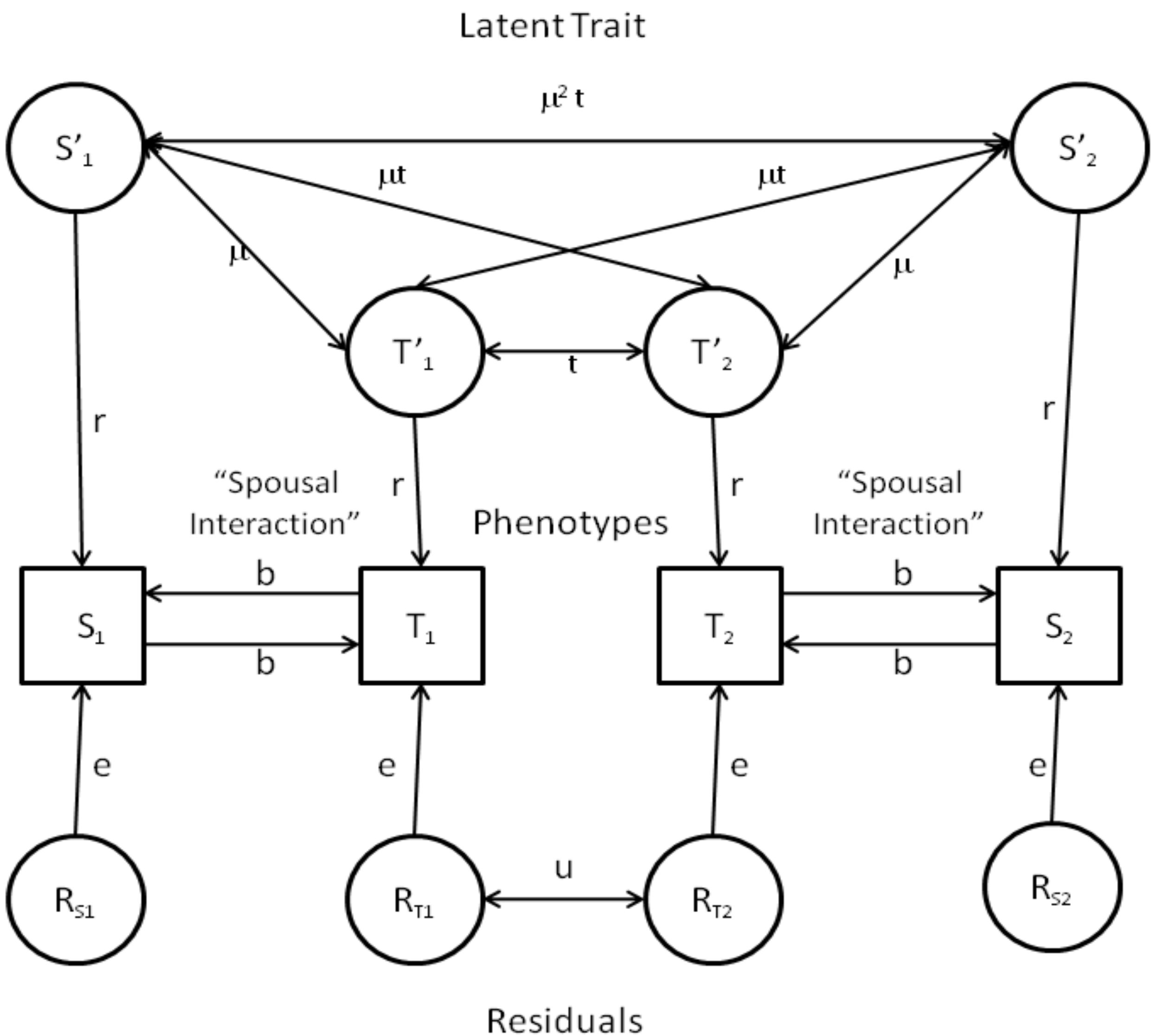


**Table 19: Goodness-of-fit statistics (weighted residual sums of squares, $S^2$) for selected models for assortative mating in the US and Australia**

| Model | | Random mating | Phenotypic assortment (P) | P+Error | Spousal Interaction | Social Homogamy |
|---|---|---|---|---|---|---|
| d.f. | | 16 | 15 | 13 | 14 | 11 |
| Variable | Sample | $S^2$ | $S^2$ | $S^2$ | $S^2$ | $S^2$ |
| Stature | US | 449.179 | 31.363 | 24.423[1] | 78.930 | 28.786 |
| | AU | 239.827 | 12.947 | 11.817[1] | 31.694 | 25.353 |
| Conservatism | US | 2535.373 | 14.845 | 12.143 | 118.266 | 328.491 |
| | AU | 2041.407 | 31.627 | 29.669 | 113.276 | 239.123 |
| Neuroticism | US | 63.371 | 17.811 | See note[2] | 20.226 | 19.458 |
| | AU | 28.337 | 17.444 | See note[2] | 15.583 | 22.807 |
| Church attendance | US | 3375.872 | 15.187 | 12.841 | 103.042 | 611.006 |
| | AU | 3019.544 | 22.140 | 21.548[1] | 76.574 | 403.950 |
| Political affiliation | US | 2213.625 | 22.254 | 18.500 | 87.889 | 429.819 |
| | AU | 2337.500 | 34.183 | 32.537 | 70.696 | 322.685 |
| Educational attainment | US | 2477.957 | 46.210 | 28.207 | 243.100 | 57.774 |
| | AU | 1430.440 | 44.146 | 18.624 | 160.747 | 82.086 |

Notes:

[1] Estimated regression of male outcome on latent trait on upper bound (1.000).

[2] This model is poorly identified for Neuroticism because the correlation between mates is close to zero. Stable parameter estimates are not available.

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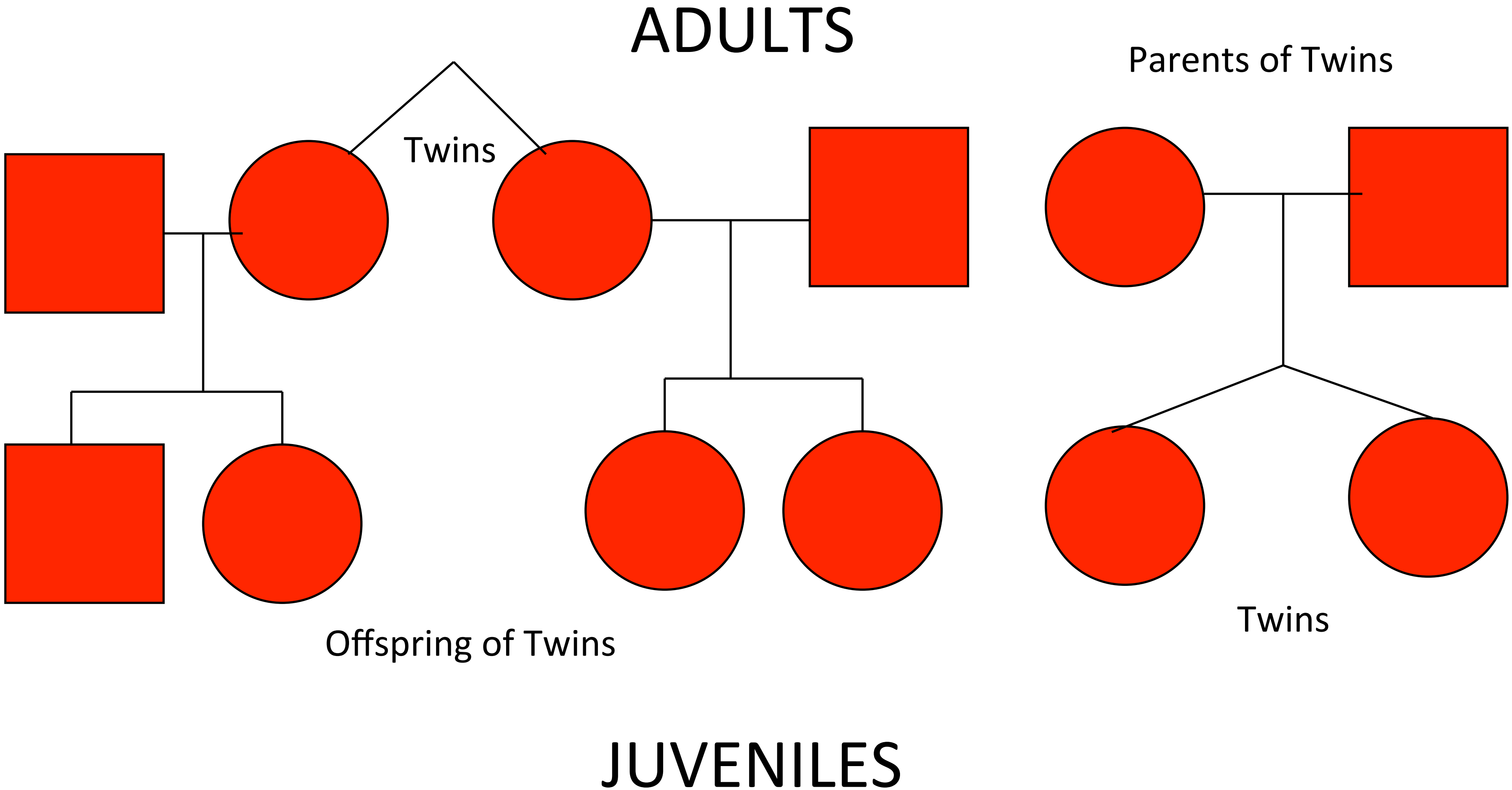
*J Child Psychol Psychiatry*. 2010 June 1; 51(6): 734–744. doi:10.1111/j.1469-7610.2010.02205.x.

# Genetic and environmental influences on the transmission of parental depression to children's depression and conduct disturbance: An extended Children of Twins study

**Judy L. Silberg**[1], **Hermine Maes**[1], and **Lindon J. Eaves**[1]

[1] Virginia Institute for Psychiatric and Behavioral Genetics, Department of Human and Molecular Genetics, Virginia Commonwealth University, Richmond, VA USA

# E-COT

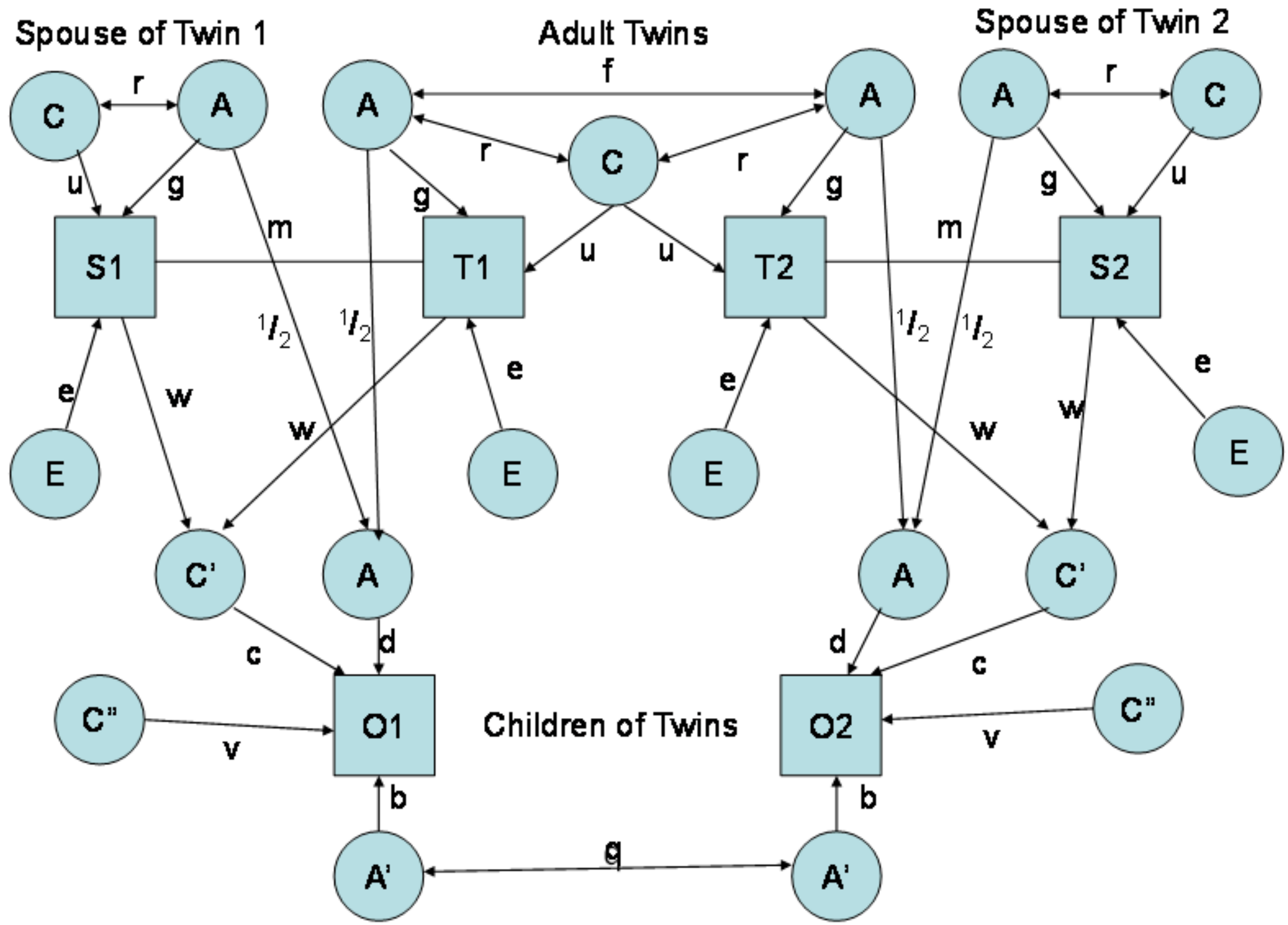

ADULTS
Parents of Twins
Twins
Twins
Offspring of Twins
JUVENILES

# Twin, parent - child, avuncular – offspring, and cousin correlations for MZ and DZ twins.

| **Twin correlations** | **Depression**[*] | **Conduct Disturbance**[**] |
|---|---|---|
| MZ adult [1] | .32 (n=498) | |
| DZ adult [1] | .12 (n=545) | |
| MZ child [2] | .34 (n=692) | .73 (n=684) |
| DZ child [2] | .17 (n=645) | .34 (n=627) |
| **Adult - Child correlations** [3] | | |
| MZ parent | .18 (n=753) | .21 (n=1347) |
| DZ parent | .20 (n=845) | .23 (n=1508) |
| MZ avuncular | .07 (n=661) | .11 (n=1141) |
| DZ avuncular | .01 (n=654) | .06 (n=1129) |
| **Cousin Correlations** | | |
| MZ twin pair families | .01 (n=261) | .15 (n=526) |
| DZ twin pair families | .02 (n=185) | .15 (n=441) |

[1] Adult twin correlations - Children of Twins Study (COT)
[2] Juvenile twin correlations - Virginia Twin Study of Adolescent Behavioral Development (VTSABD)
[3] Complete and incomplete twin pair families
[*] Child ratings of depression
[**] Parental ratings of conduct

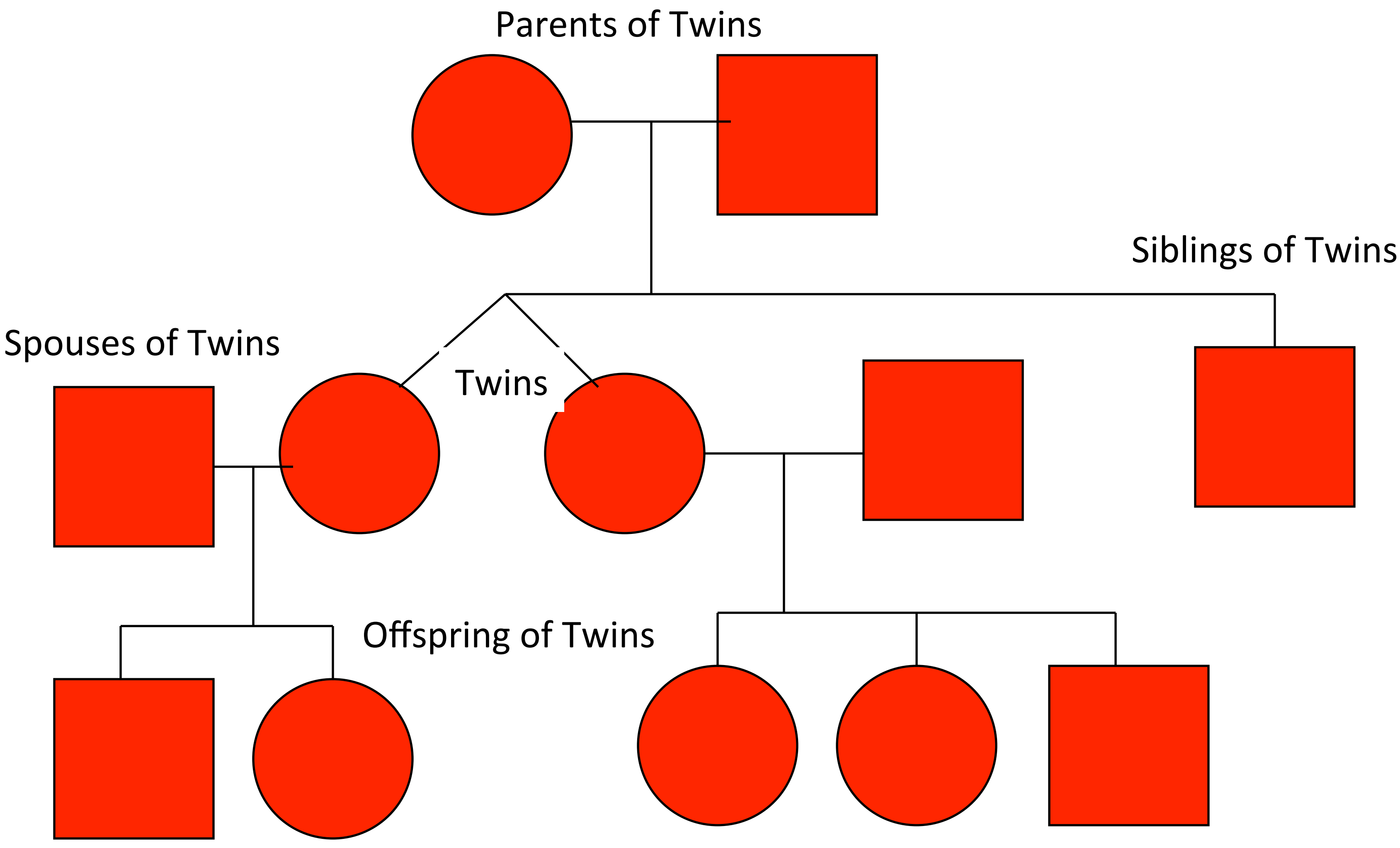
# Children of Twins Model (COT)



# Parental Depression and Childhood Outcomes: Results

| Parameter | **Depression** | **Conduct** | **Parameter Descriptiion** | **Free?** |
|---|---|---|---|---|
| m | **0.1761** | **0.2064** | Correlation between spouses | F |
| g | **0.5410** | **0.5426** | Path from persistent additive genetic effect to adult phenotype | F |
| d | **0.0000!** | **0.3898** | Path from persistent additive genetic effect to juvenile phenotype | F |
| b | **0.5339** | **0.6775** | Path from juvenile limited genetic effect to juvenile phenotype | F |
| u | **0.0000!** | **0.0000!** | Path from adult shared environment to adult phenotype | F |
| w | **0.6520** | **0.6438** | Path from parental phenotype to juvenile shared environment | D |
| c | **0.2101** | **0.1304** | Path from juvenile shared environment to juvenile phenotype | F |
| v | **0.0000!** | **0.0000!** | Path from juvenile-specific shared environment to phenotype | F |
| r | **0.4149** | **0.4215** | Correlation between persistent genetic and shared environmental effects | D |
| wc | **0.1369** | **0.0839** | Path from parental phenotype to juvenile shared environment | D |
| a | **0.5410** | **0.5246** | Correlation between genes of parents and phenotype of parents | D |
| f | **0.5226** | **0.5303** | Correlation between additive genetic effects of siblings/twins | D |
| $\chi^2$ | **0.325** | **1.218** | | |
| d.f. | **3** | **2** | | |
| P | **0.9552** | **0.5438** | | |

# The Full Monty



# Genetic and Environmental Factors in Relative Body Weight and Human Adiposity

**Hermine H. M. Maes, Michael C. Neale and Lindon J. Eaves.**

*Behavior Genetics, Vol. 27. No. 4, 1997*

**Table VI.** Observed Correlations of BMI for Biological Relationships in the Virginia 30,000 (Eaves, Unpublished Data)[a]

| Family | *N* | *r* | Avuncular | *N* | *r* | Cousins | *N* | r | In-laws | *N* | *r* | | *N* | *r* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | 4751 | .144 | PSib♂♂ | 92 | −.026 | Mzm♂♂ | 39 | .094 | SibI♂♀ | 337 | −.075 | SPDz♀♂ | 54 | −.223 |
| | | | PSib♂♀ | 155 | .004 | Mzm♀♀ | 92 | .223 | SibI♀♂ | 728 | −.007 | SPDz♀♀ | 80 | −.177 |
| Sib♂♂ | 1493 | .234 | NSib♀♂ | 402 | .185 | Mzm♂♀ | 107 | .185 | SibI♂♂ | 422 | .077 | SNDz♂♂ | 126 | .114 |
| Sib♀♀ | 3524 | .317 | NSib♀♀ | 536 | .083 | Mzf♂♂ | 153 | .040 | SibI♀♀ | 447 | .075 | SND♂♀ | 169 | −.043 |
| Sib♂♀ | 4255 | .224 | PSib♀♂ | 131 | −.007 | Mzf♀♀ | 340 | .191 | | | | SPDz♂♂ | 36 | −.255 |
| | | | PSib♀♀ | 196 | .065 | Mzf♂♀ | 449 | .064 | DzI♂♀ | 387 | .047 | SPDz♂♀ | 68 | .146 |
| DZ♂♂ | 573 | .292 | NSib♂♂ | 236 | .105 | | | | DzI♀♂ | 603 | .126 | SNDz♀♂ | 64 | .090 |
| Dz♀♀ | 1164 | .360 | NSib♂♀ | 284 | .059 | Dzm♂♂ | 19 | −.375 | DzI♂♂ | 353 | .038 | SNDz♀♀ | 95 | .106 |
| Dz♂♀ | 1307 | .264 | | | | Dzm♀♀ | 41 | .070 | DzI♀♀ | 458 | −.028 | | | |
| Mz♂♂ | 775 | .692 | PDz♂♂ | 105 | .292 | Dzm♂♀ | 52 | −.072 | MzI♂♀ | 589 | .048 | SPMz♀♂ | 129 | .014 |
| Mz♀♀ | 1847 | .730 | PDz♂♀ | 137 | .016 | Dzf♂♂ | 52 | .260 | MzI♀♂ | 1139 | .109 | SPMz♀♀ | 213 | .062 |
| | | | NDz♀♂ | 345 | .152 | Dzf♀♀ | 138 | .095 | | | | SNMz♂♂ | 342 | −.107 |
| Fa–So | 2160 | .190 | NDz♀♀ | 525 | .176 | Dzf♂♀ | 159 | −.025 | Fa-DaI | 205 | −.068 | SNMz♂♀ | 502 | .040 |
| Fa–Da | 2971 | .194 | PDz♀♂ | 118 | .393 | Dzo♂♂ | 38 | .176 | Fa-SoI | 188 | .044 | | | |
| Mo–So | 3035 | .227 | PDz♀♀ | 188 | −.001 | Dzo♀♀ | 71 | .118 | Mo-DaI | 293 | .024 | SDzm | 100 | .126 |
| Mo–Da | 4476 | .257 | NDz♂♂ | 150 | .185 | Dzo♂♀ | 51 | −.118 | Mo-SoI | 338 | .102 | SDzf | 120 | −.065 |
| | | | NDz♂♀ | 202 | .098 | Dzo♀♂ | 72 | .141 | | | | SDzmf | 167 | −.057 |
| | | | | | | | | | | | | SMzm | 172 | .025 |
| | | | PMz♂♂ | 217 | .141 | | | | | | | SMzf | 300 | .132 |
| | | | PMz♂♀ | 337 | .264 | | | | | | | | | |
| | | | NMz♀♂ | 673 | .124 | | | | | | | | | |
| | | | NMz♀♀ | 1040 | .255 | | | | | | | | | |

[a] S, spouse; Sib, sibling; Dz, DZ twin; Mz, MZ twin; Fa, father; Mo, mother; So, son; Da, daughter; P, paternal; N, maternal; I, in-laws; m, male; f, female; o, opposite sex; ♂♂, male–male pair; ♀♀, female–female pair; ♂♀, male–female pair; ♀♂, female–male pair.

# The “Stealth” Model

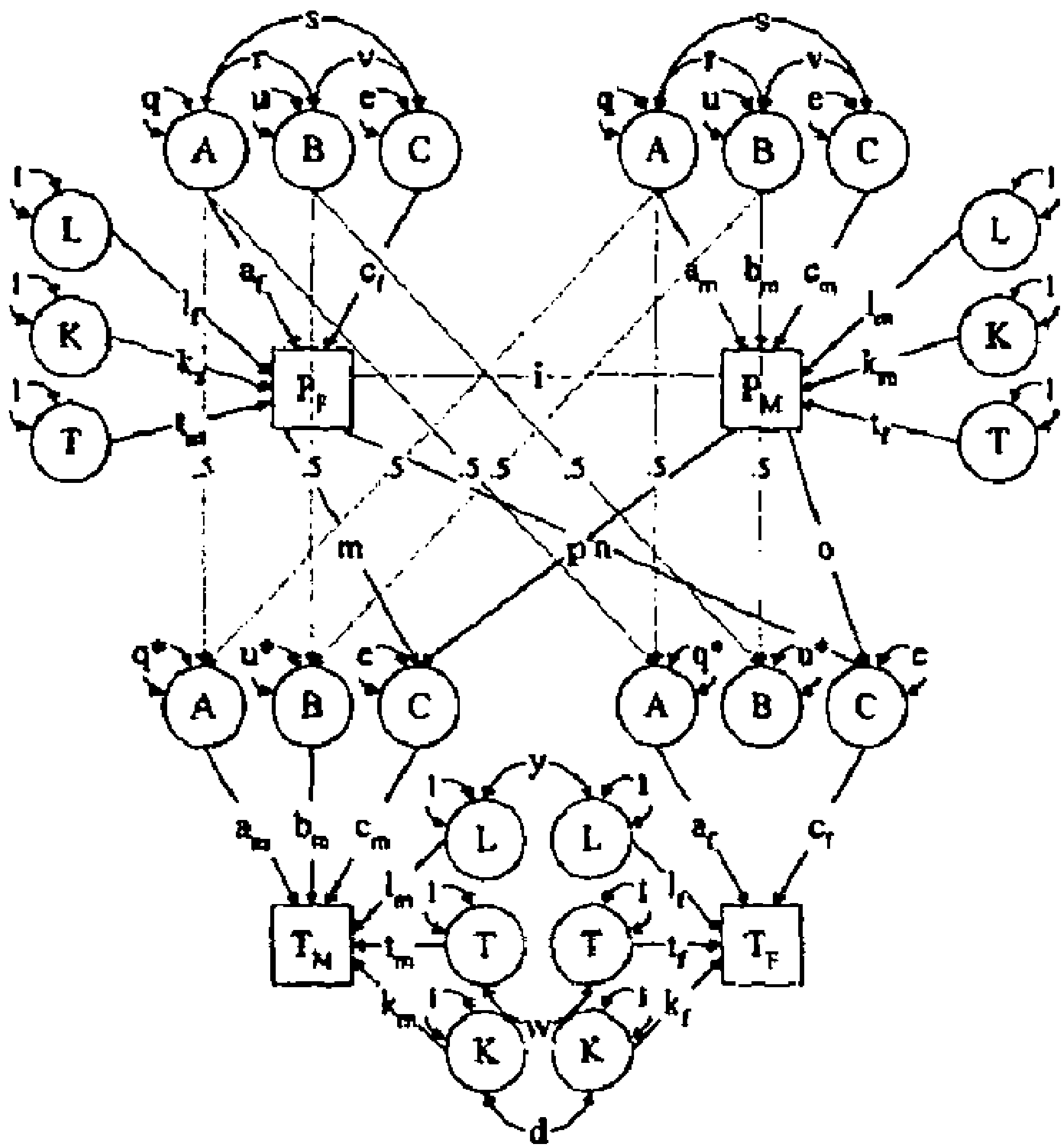


**Table V.** Statistics, Parameter Estimates, Proportion of Variance, and Confidence Intervals of the Best-Fitting Model for BMI in the Virginia 30,000[a]

| Full model with special MZ twin environment | | Parameter estimate of Full model without special MZ twin environment | | Best-fitting model | | Proportion of variance of best-fitting model | | Confidence intervals |
|---|---|---|---|---|---|---|---|---|
| $A^2_m$ | .28+.16 | $A^2_m$ | .19+.20 | $A_m$ | .521 | $A^2_m$ | .351 | .290–.415 |
| (asm) | .01 | (asm) | .01 | $A_f$ | .637 | (asm) | (.020) | |
| $D^2_m$ | .00 | $D^2_m$ | .27 | $E_m$ | .474 | $D^2_m$ | .307 | .211–.395 |
| $E^2_m$ | .23 | $E^2_m$ | .27 | $E_f$ | .543 | $E^2_m$ | .274 | .247–.304 |
| $CT^2_m$ | .00 | $CT^2_m$ | .00 | $D_m$ | .501 | $T^2_m$ | .068 | .023–.134 |
| $S^2_m$ | −.01 | $S^2_m$ | .01 | $D_f$ | .532 | | | |
| $C^2_m$ | .02 | $C^2_m$ | .00 | $T_m$ | −.236 | $A^2_f$ | .394 | .350–.437 |
| $T^2_m$ | .03 | $T^2_m$ | .03 | $T_f$ | .292 | (asm) | (.022) | |
| $Tmz^2_m$ | .24 | $Tmz^2_m$ | | $P_m$ | 1.094 | $D^2_f$ | .259 | .192–.324 |
| $A^2_T$ | .26 | $A^2_f$ | .28 | $P_f$ | .819 | $E^2_f$ | .269 | .252–.288 |
| (asm) | .01 | (asm) | .01 | $I$ | .159 | $T^2_f$ | .078 | .033–.128 |
| $D^2_f$ | .00 | $D^2_f$ | .32 | | | | | |
| $E^2_f$ | .21 | $E^2_T$ | .27 | | | | | |
| $CT^2_f$ | .00 | $CT^2_f$ | .01 | | | | | |
| $S^2_f$ | .03 | $S^2_f$ | .03 | | | | | |
| $C^2_f$ | .10 | $C^2_f$ | .01 | | | | | |
| $T^2_f$ | .06 | $T^2_f$ | .06 | | | | | |
| $Tmz^2_f$ | .31 | $Tmz^2_f$ | | | | | | |

[a] Goodness-of-fit statistics of best-fitting model: observed statistics, 24,230; estimated parameters, 72; constraints, 12; active constraints, 7; −2 times log-likelihood of data, 64,988.057; degrees of freedom, 24,158. $A^2$, additive genetic factors; asm, assortment; $D^2$, dominance factors; $E^2$, unique environmental factors; $CT^2$, cultural transmission; $S^2$, genotype–environment covariance; $C^2$, nonparental shared environment; $T^2$, special twin environment; $Tmz^2$, special twin environment; f and m subscripts, males and females.