Factored stochastic tree modeling for medical decision making

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Outline of talk

- What is a stochastic tree?
  - Basic concepts
  - Stochastic tree rollback
- Factoring stochastic trees
- Approximating human mortality
- Example: Testing for ovarian cancer
- The StoTree modeling environment
- Cost-effectiveness for ovarian cancer testing

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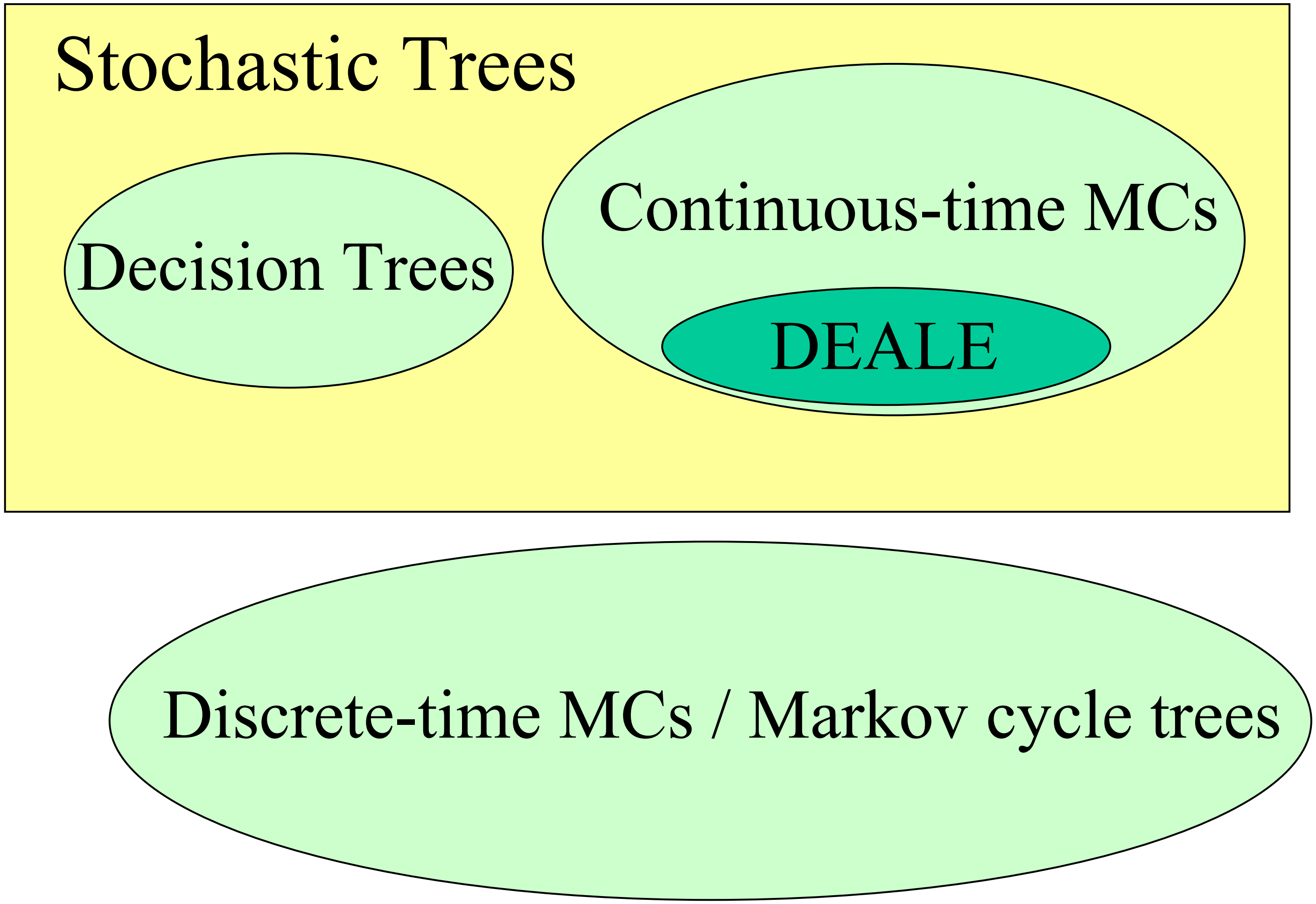
What is a stochastic tree?

- A stochastic tree is
  - A decision tree with *stochastic nodes* added
  - A continuous-time MC with chance and decision nodes added
  - A multi-state DEALE model
  - A continuous-time version of a Markov cycle tree

…What is a stochastic tree?



… What is a stochastic tree?

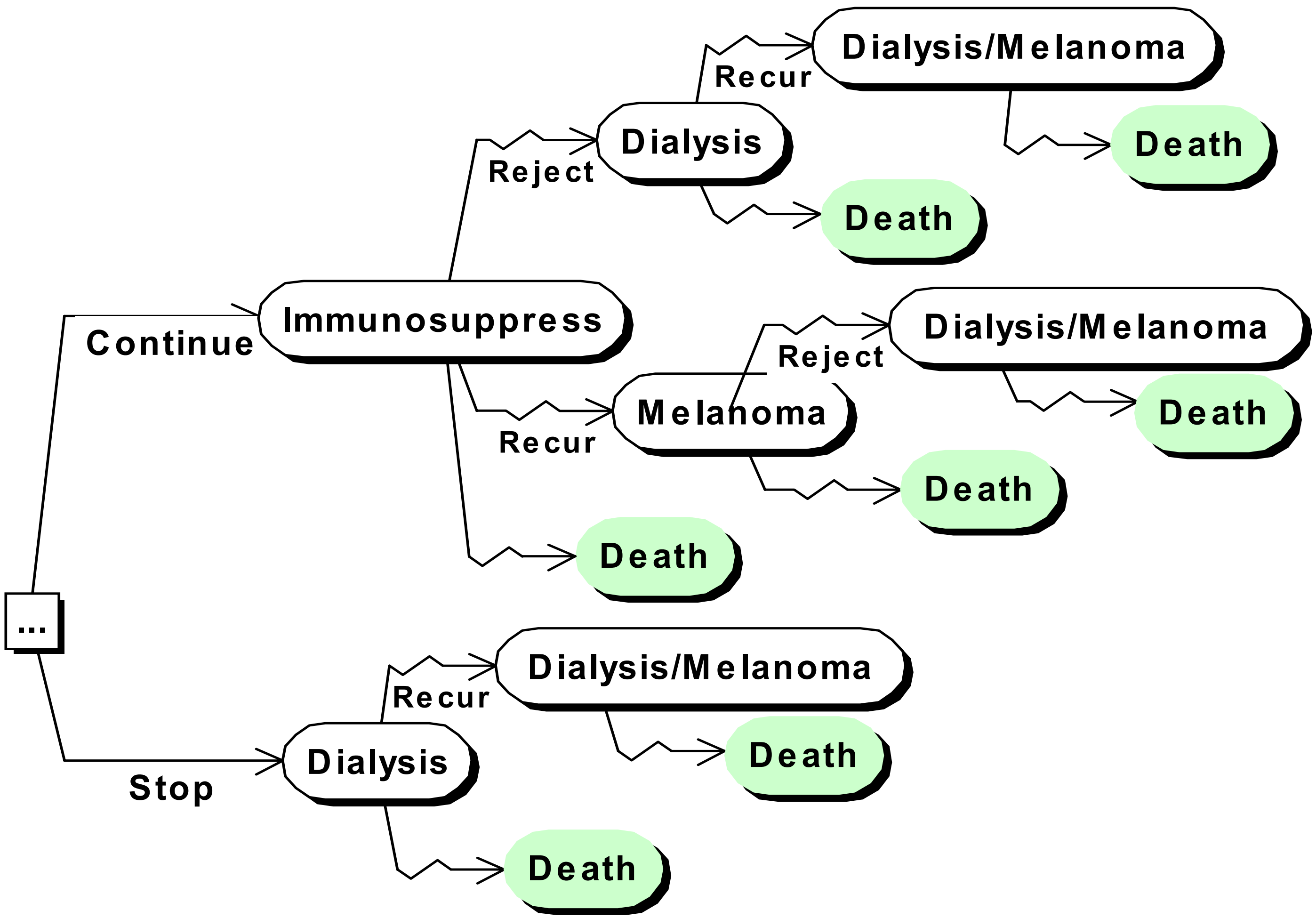
- Beck and Sonnenberg (1993):
  - 42-year old man received kidney transplant 18 months ago. Normal kidney function maintained under immunosuppressive therapy .
  - Two synchronous melanomas appeared and required wide resection.

… What is a stochastic tree?

- Should immunosuppressive therapy be continued?
  - Continuation increases chance of another possibly lethal melanoma
  - Cessation ensures kidney rejection and dialysis

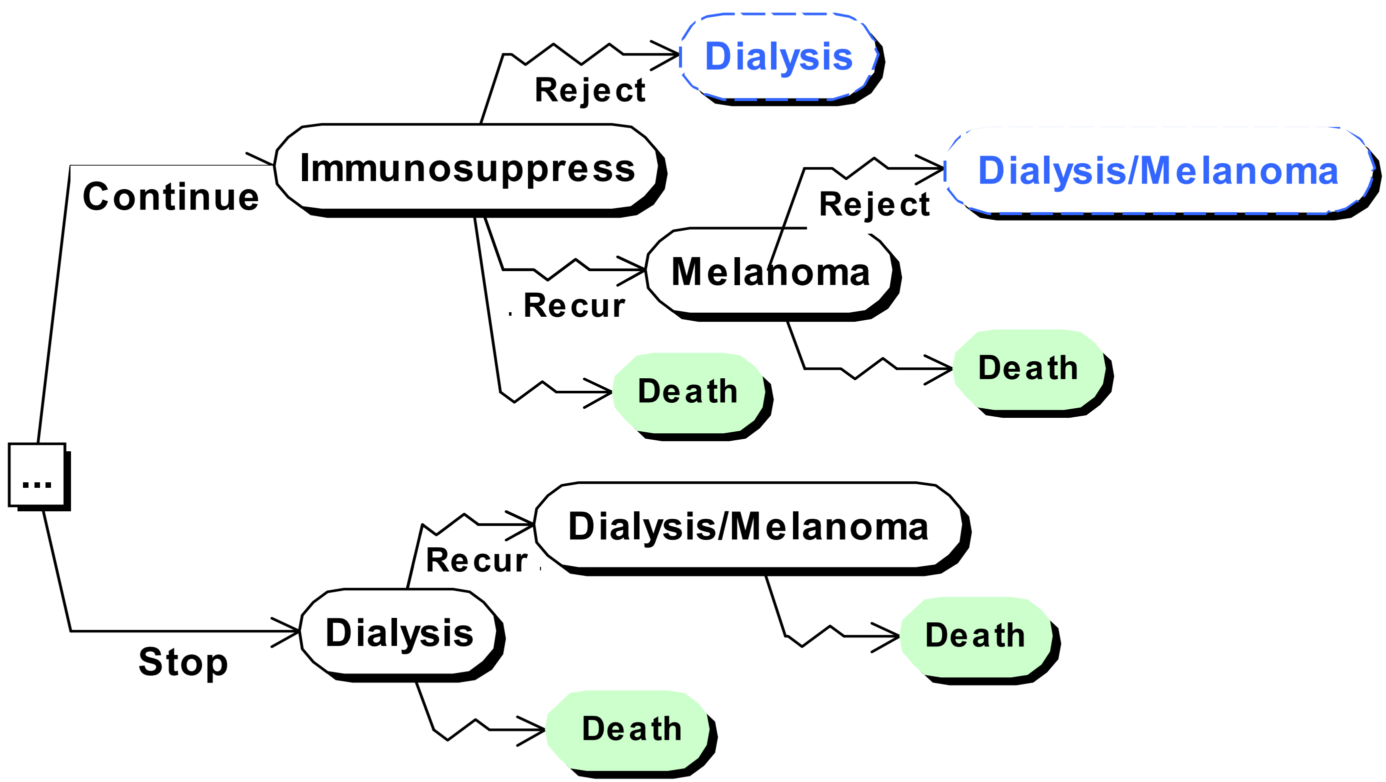
…What is a stochastic tree?

Stochastic tree representation

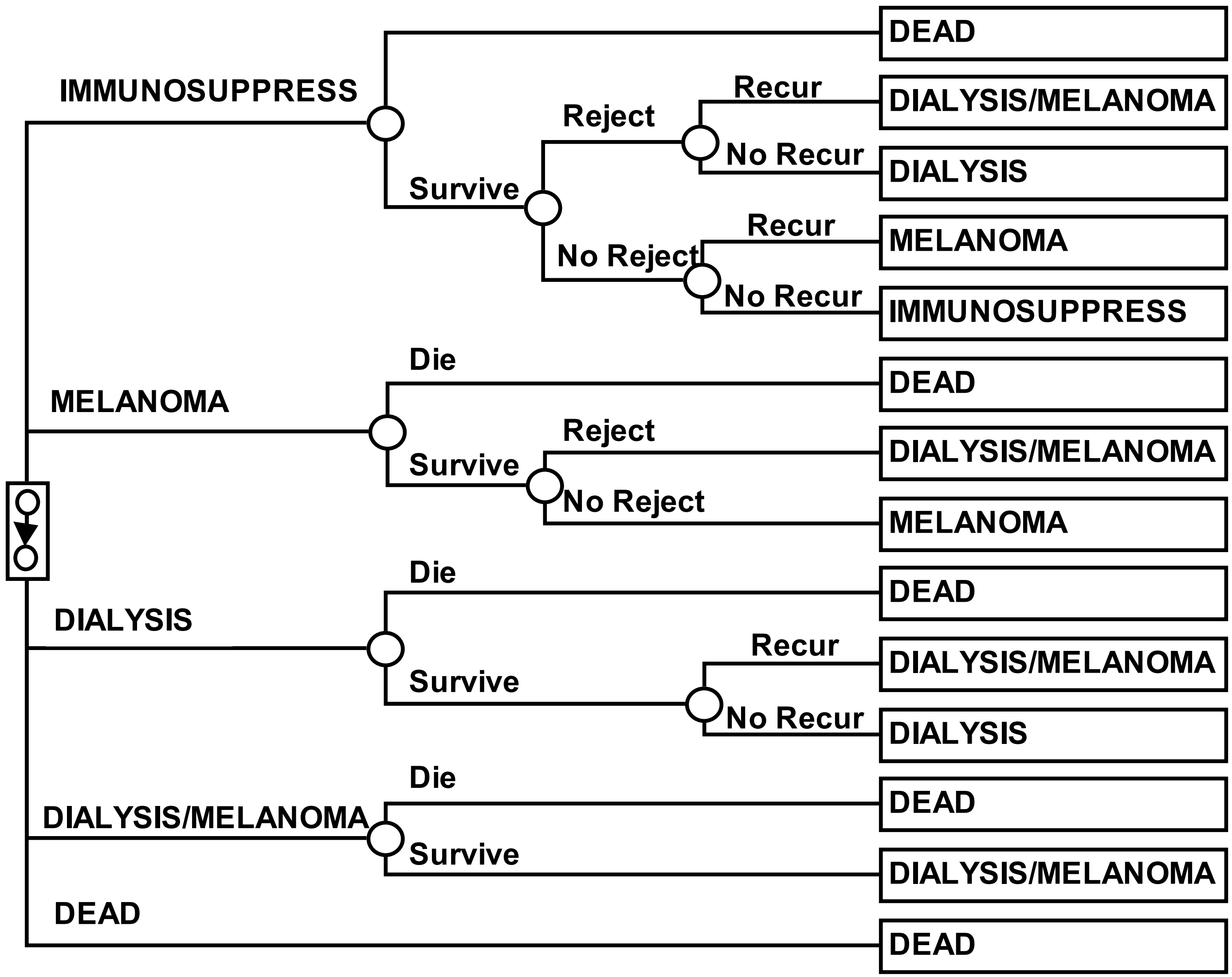


…What is a stochastic tree?

Using phantom nodes to avoid duplication

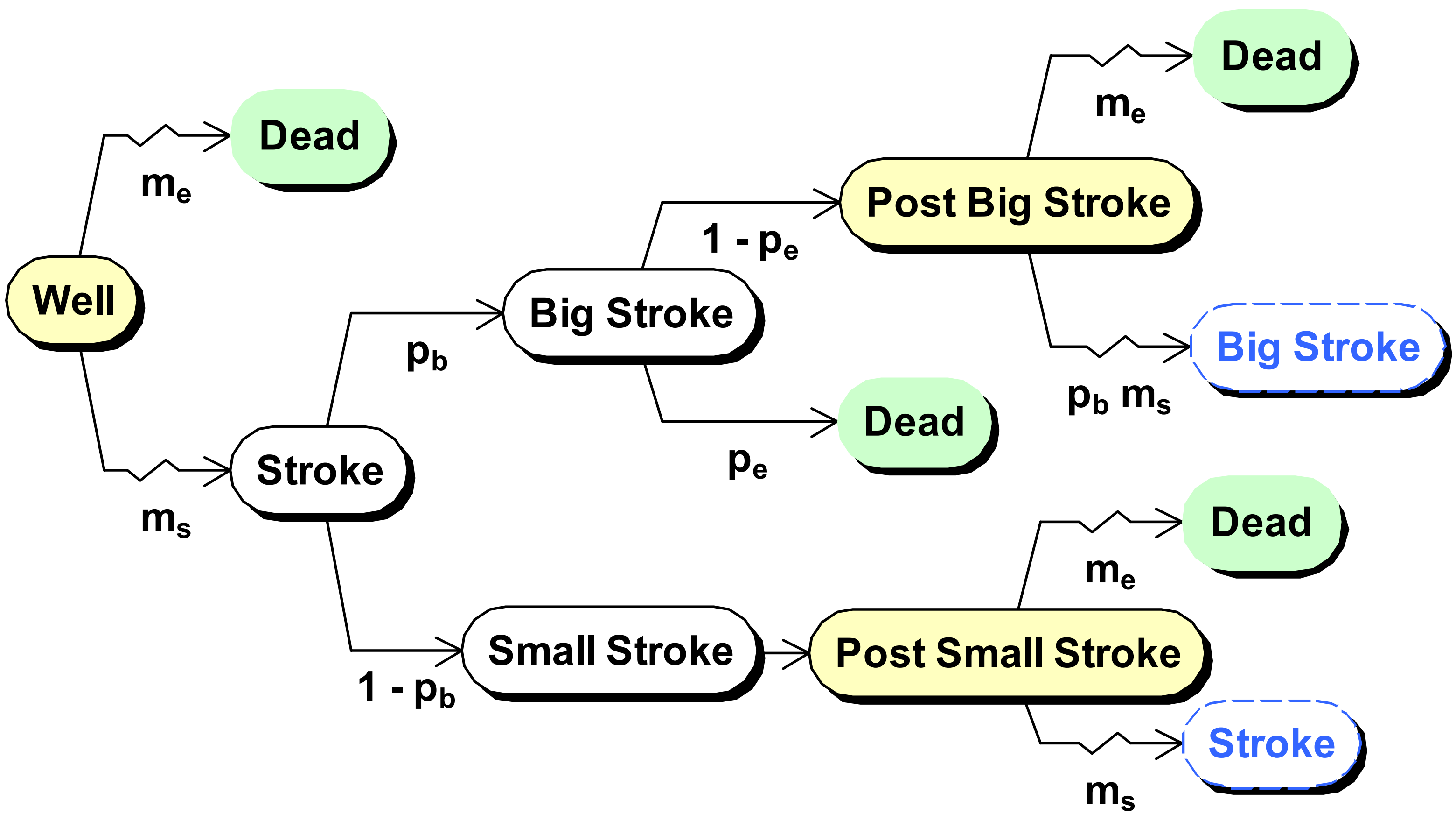


Conventional method: Markov Cycle Tree



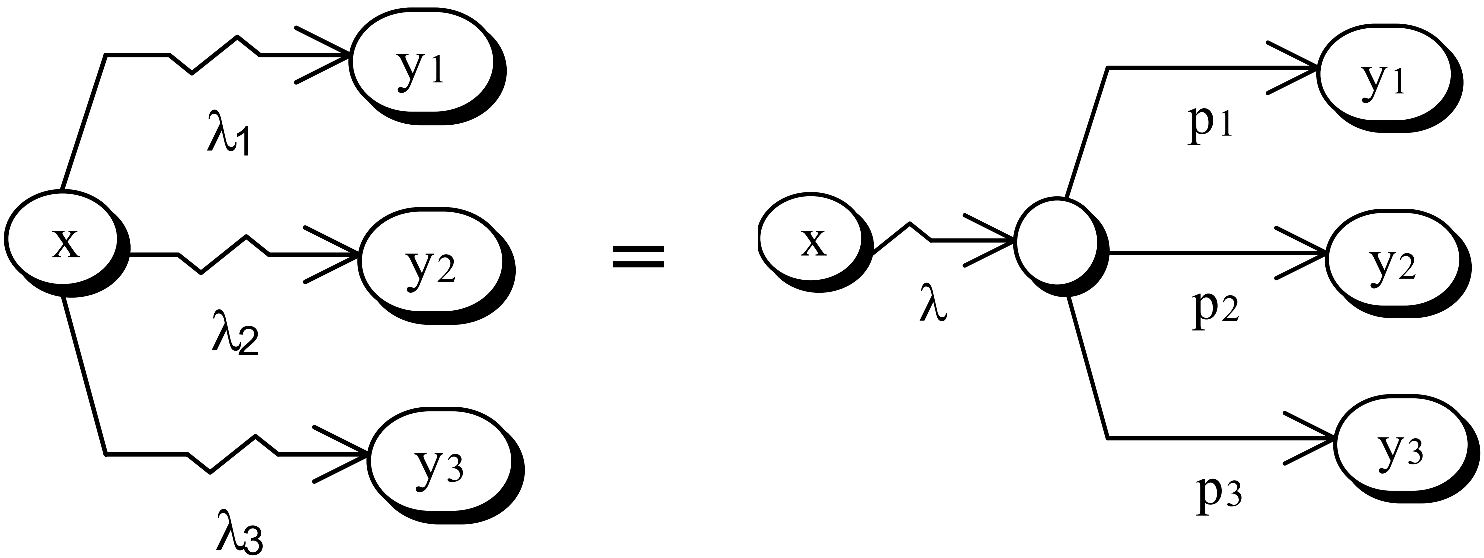
Cycles in a stochastic tree

Matchar & Pauker (1986): Transient ischemic attacks in a man with coronary artery disease



Transforming stochastic trees

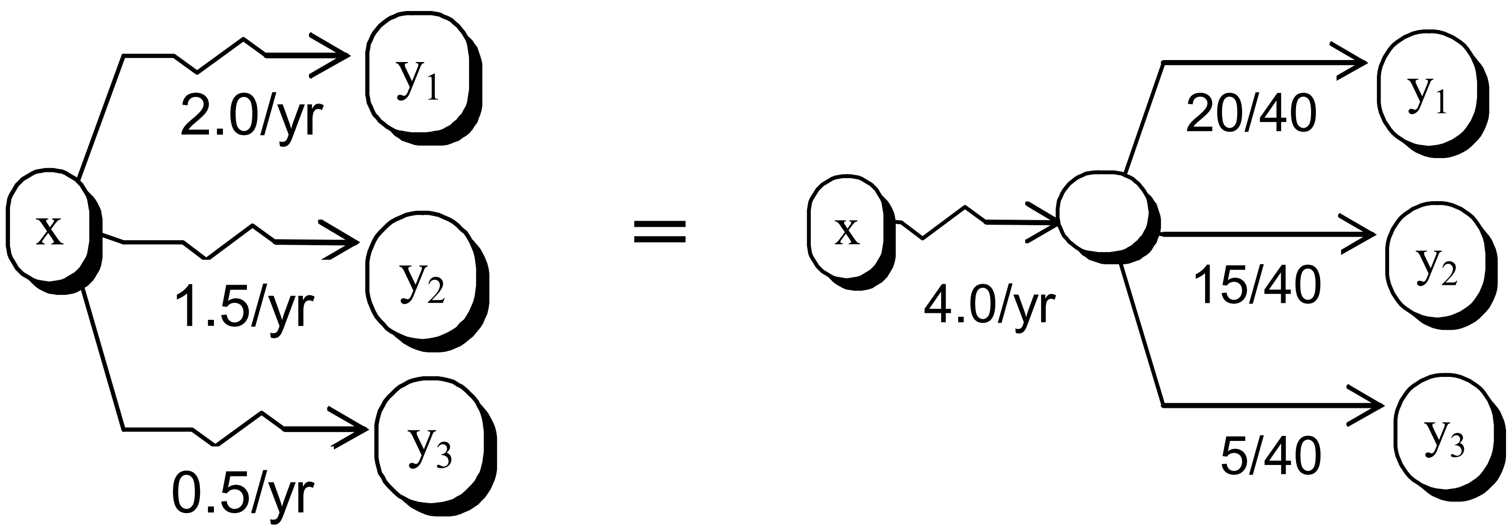
- Superposition / Decomposition



$$\lambda = \lambda_1 + \lambda_2 + \lambda_3 \qquad p_i = \frac{\lambda_i}{\lambda}$$

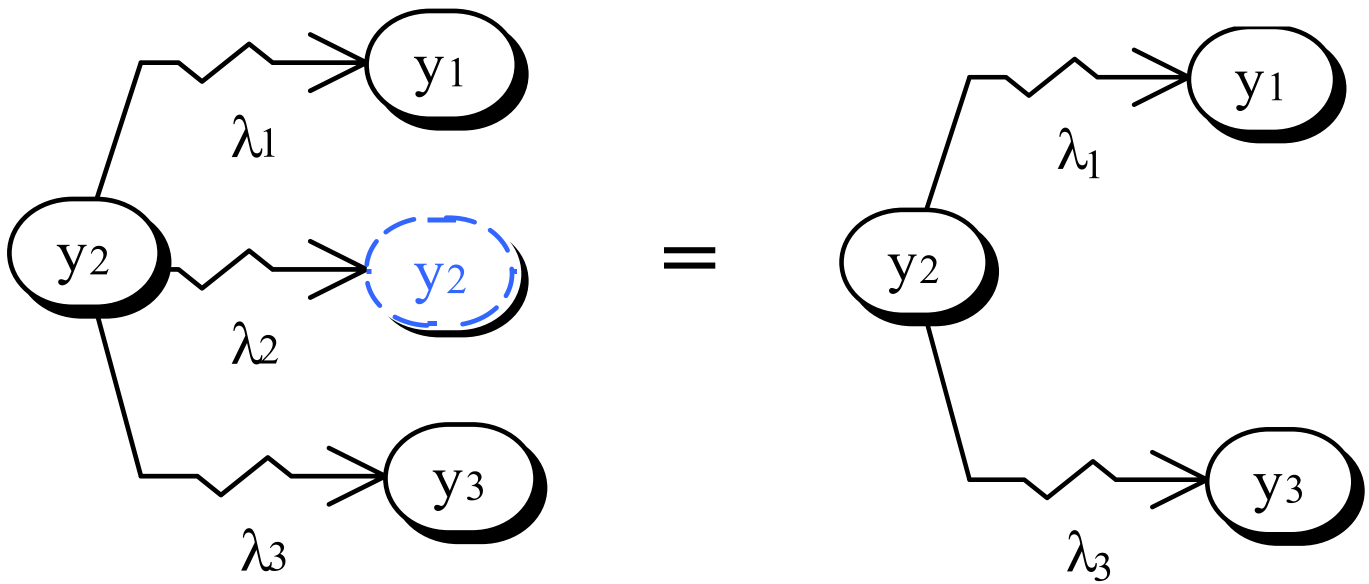
Transforming stochastic trees

- Superposition / Decomposition

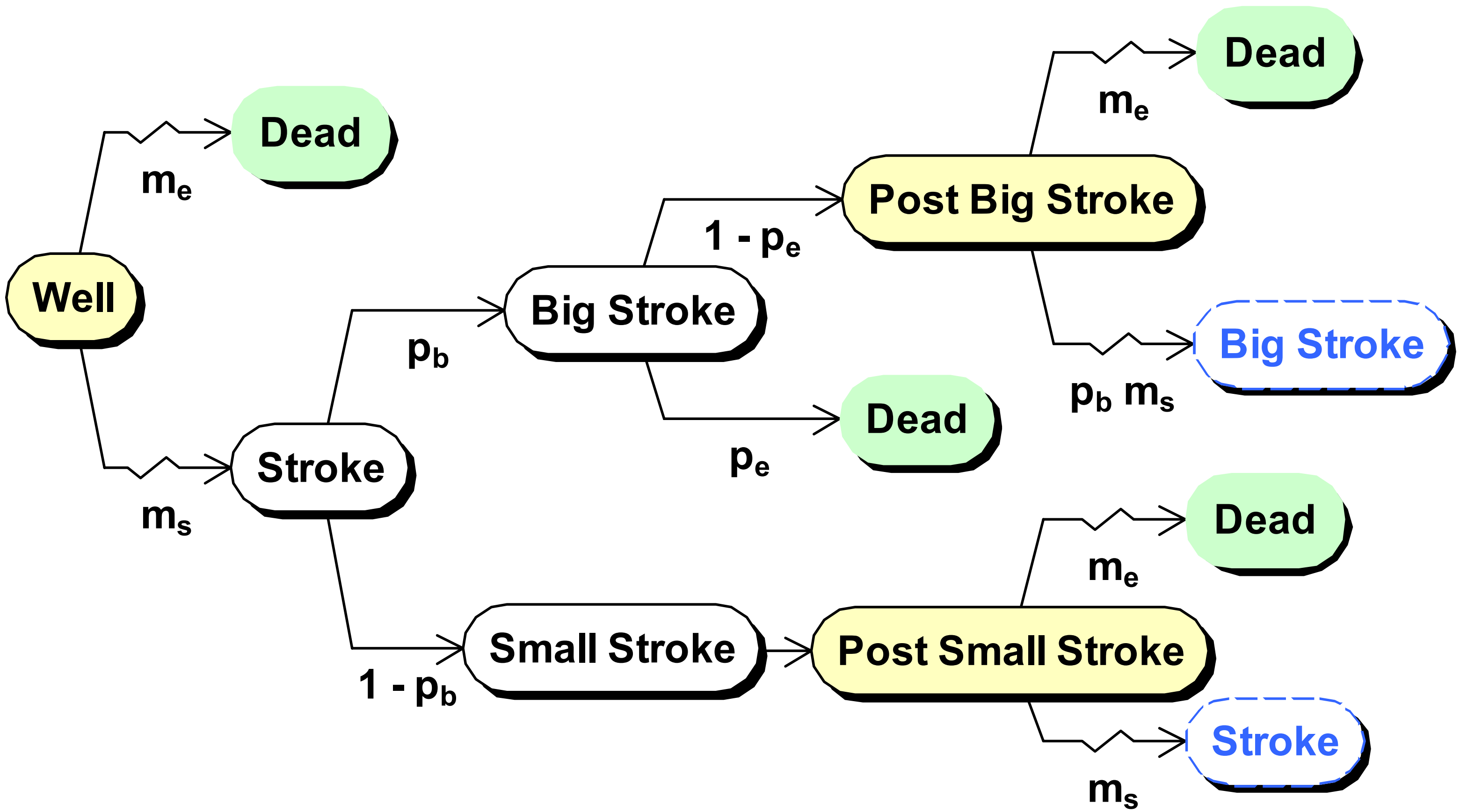


…Transforming stochastic trees

- Eliminating self-transitions



…Transforming stochastic trees



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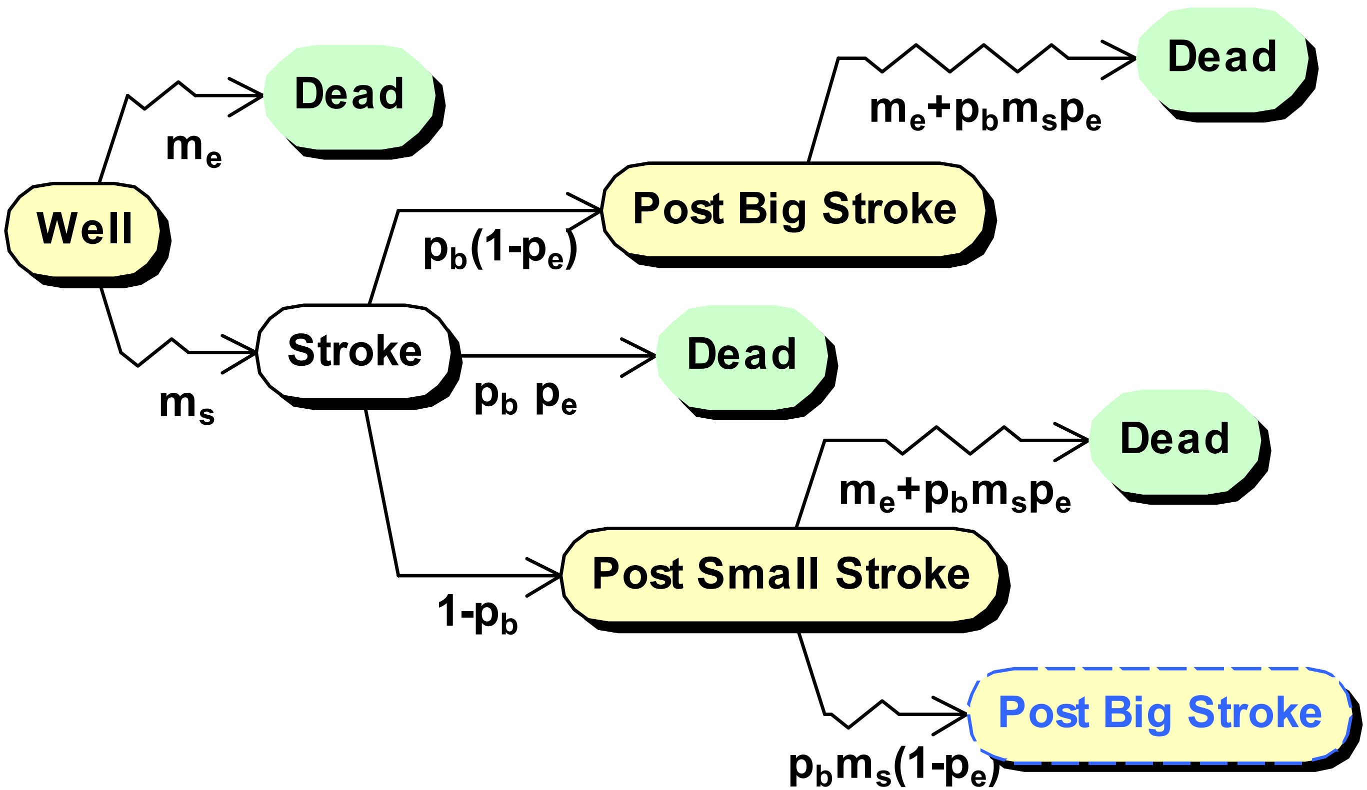

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  - **Stochastic tree rollback**
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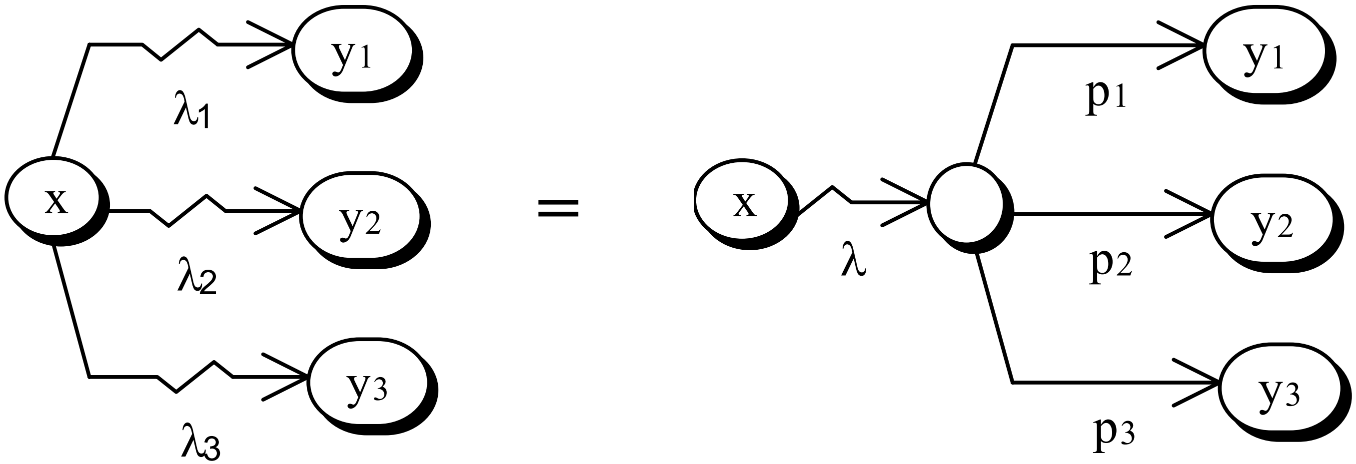
Stochastic tree rollback



L(x) = Mean QALY beginning at x

$$= v(x)\cdot\frac{1}{\lambda} + \sum_y p_y L(y) = \frac{v(x) + \sum_y \lambda_y L(y)}{\sum_y \lambda_y}$$

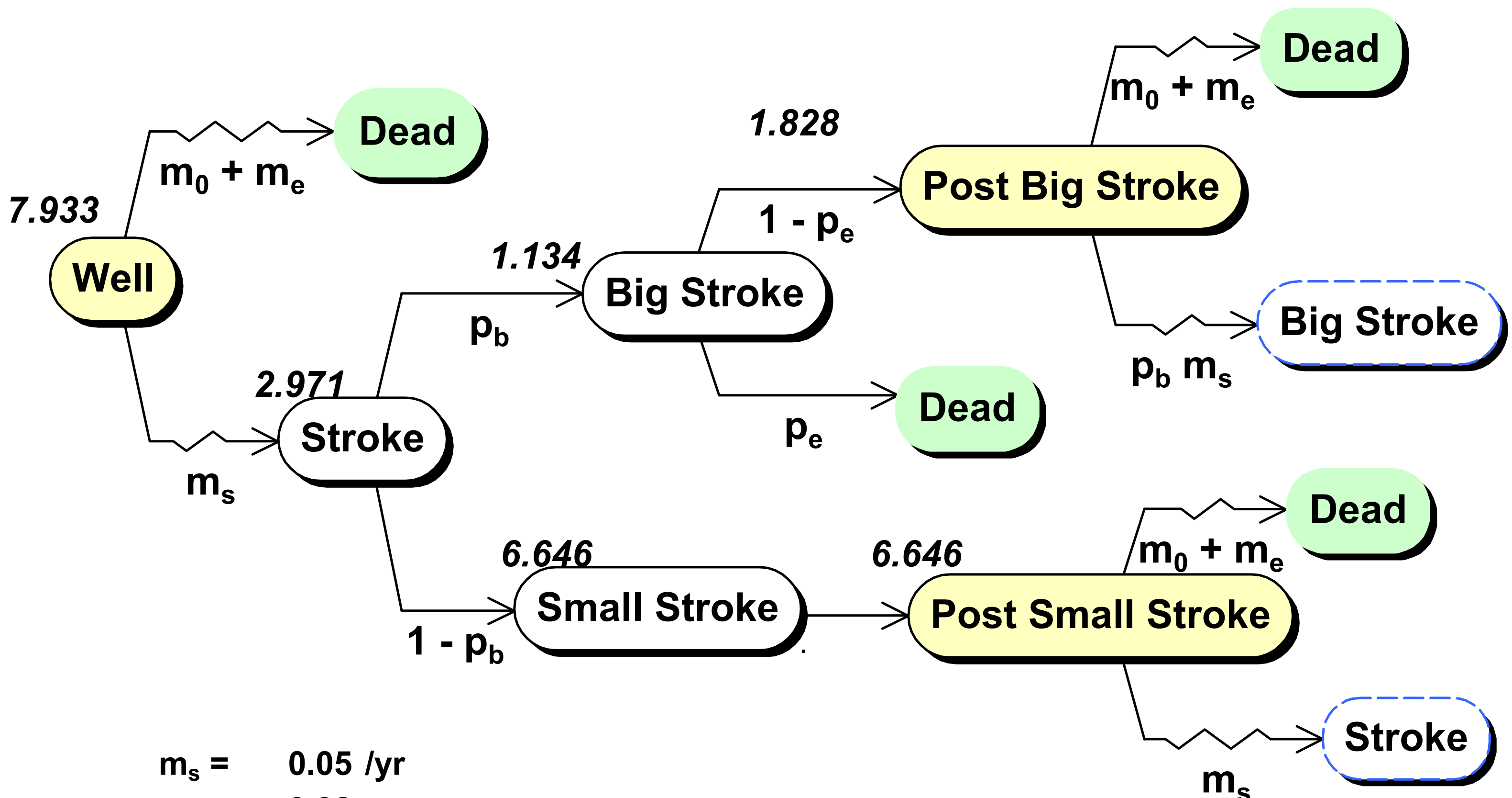
- Rollback without discounting

$$L(x) = \frac{v(x) + \sum_y \lambda_y L(y)}{\sum_y \lambda_y}$$

- Rollback with discount rate α

$$L(x) = \frac{v(x) + \sum_y \lambda_y L(y)}{\alpha + \sum_y \lambda_y}$$

Stochastic tree rollback



m_s = 0.05 /yr
p_e = 0.38
p_b = 0.6667
m_e = 0.065 /yr
m_0 = 0.0111 /yr
qPBS = 0.2
qPSS = 0.8

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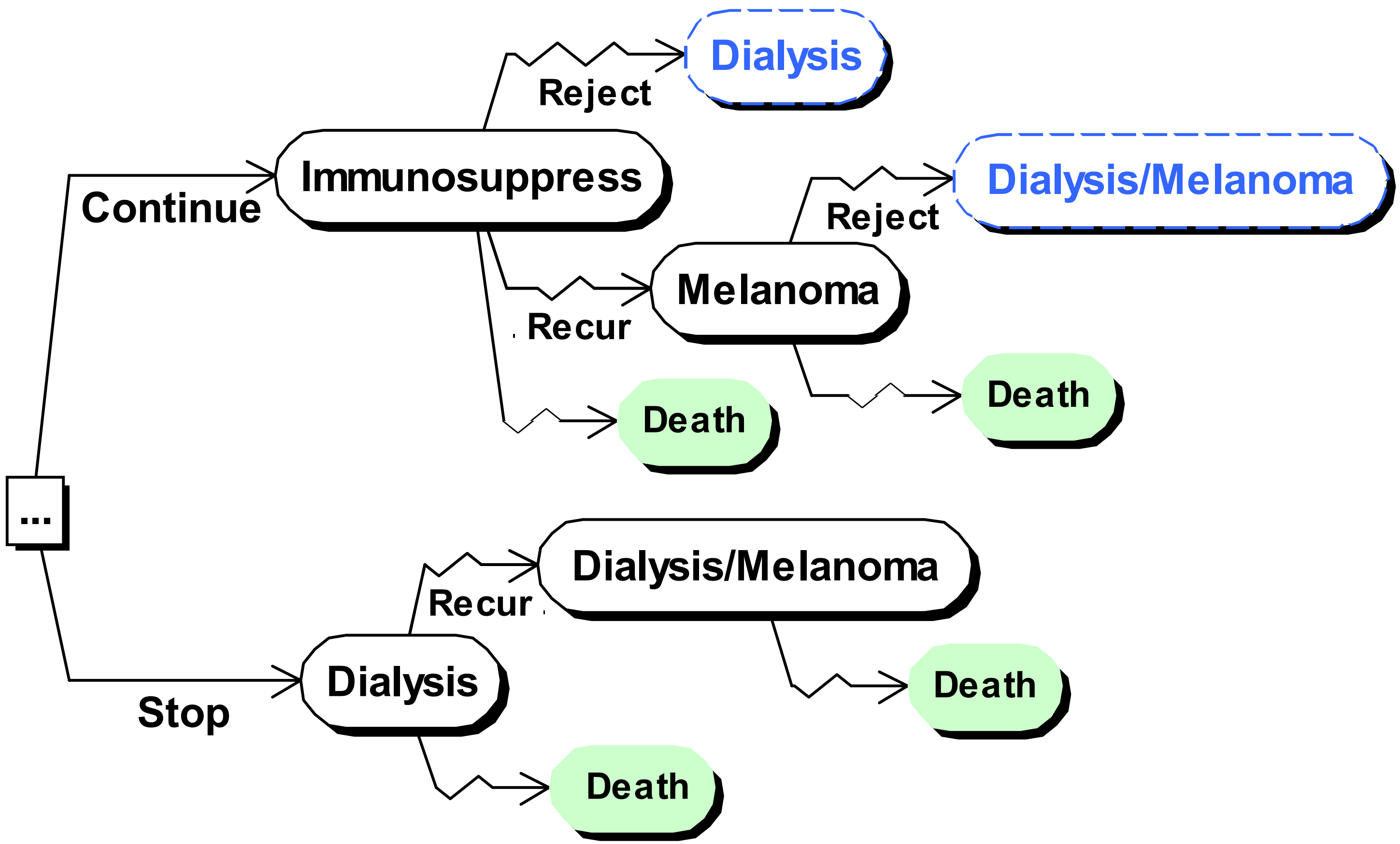
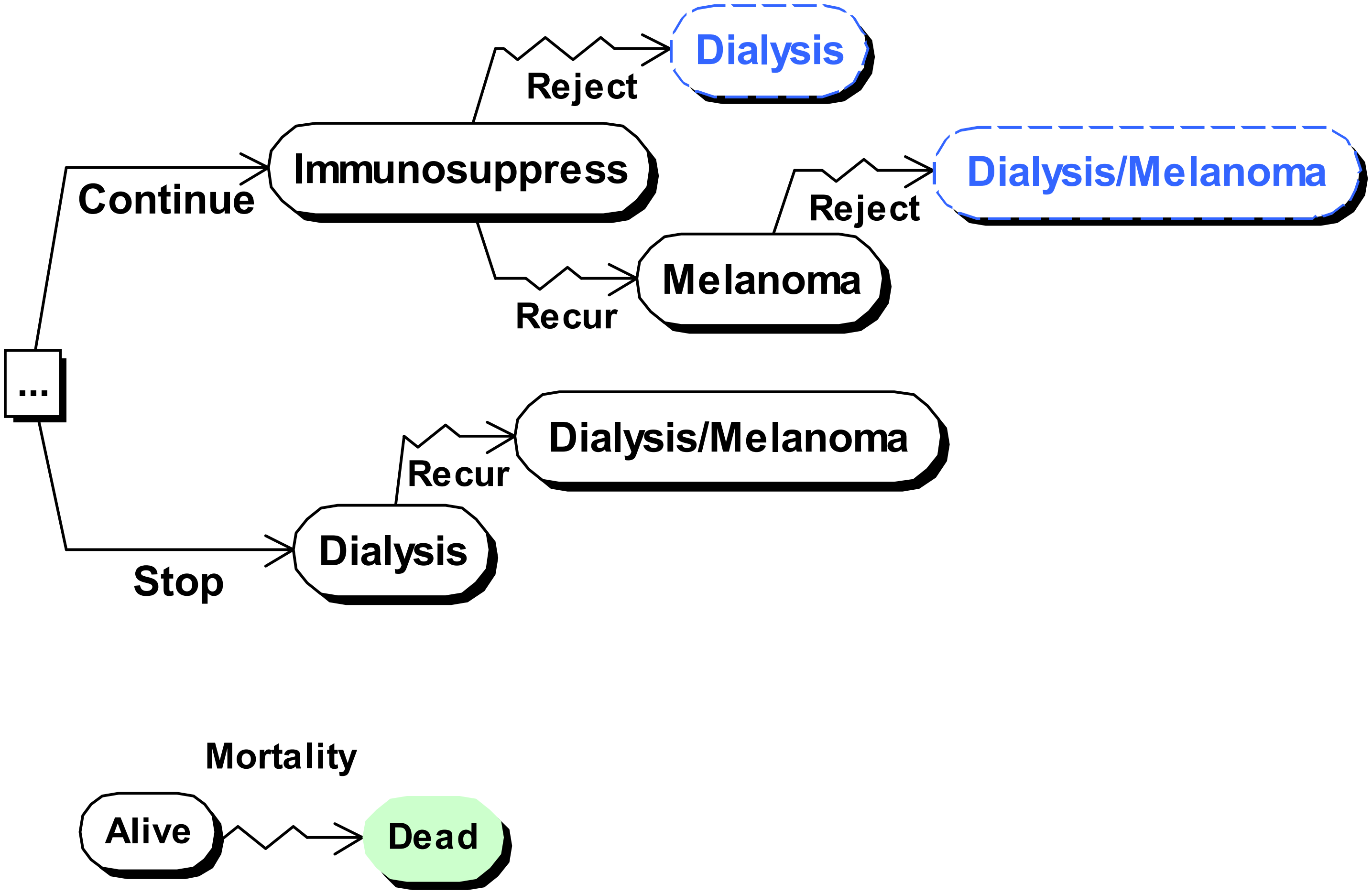
Factoring stochastic trees

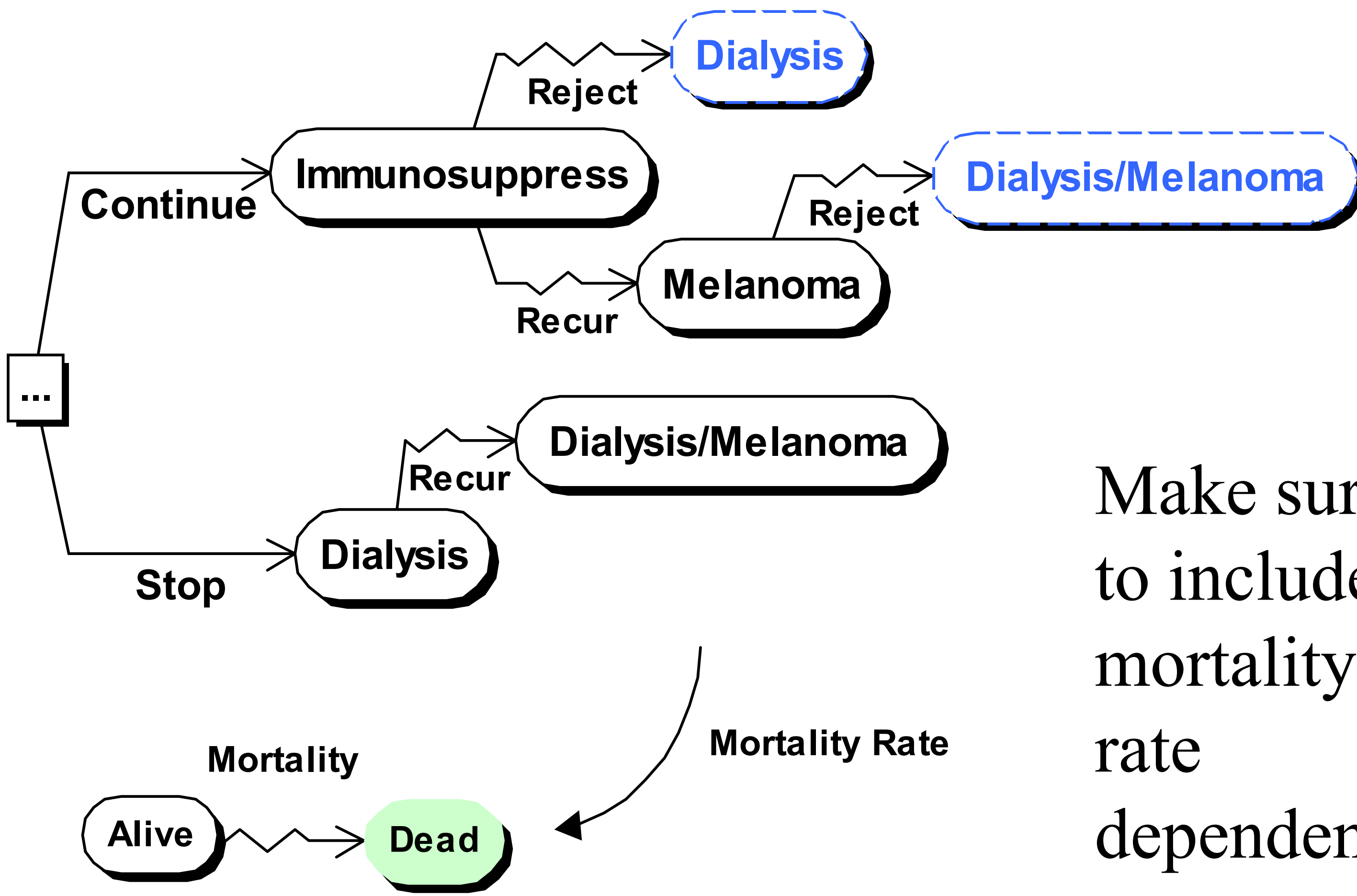


Death is a forgone conclusion, so separate it out ...

Factoring stochastic trees



Factoring stochastic trees

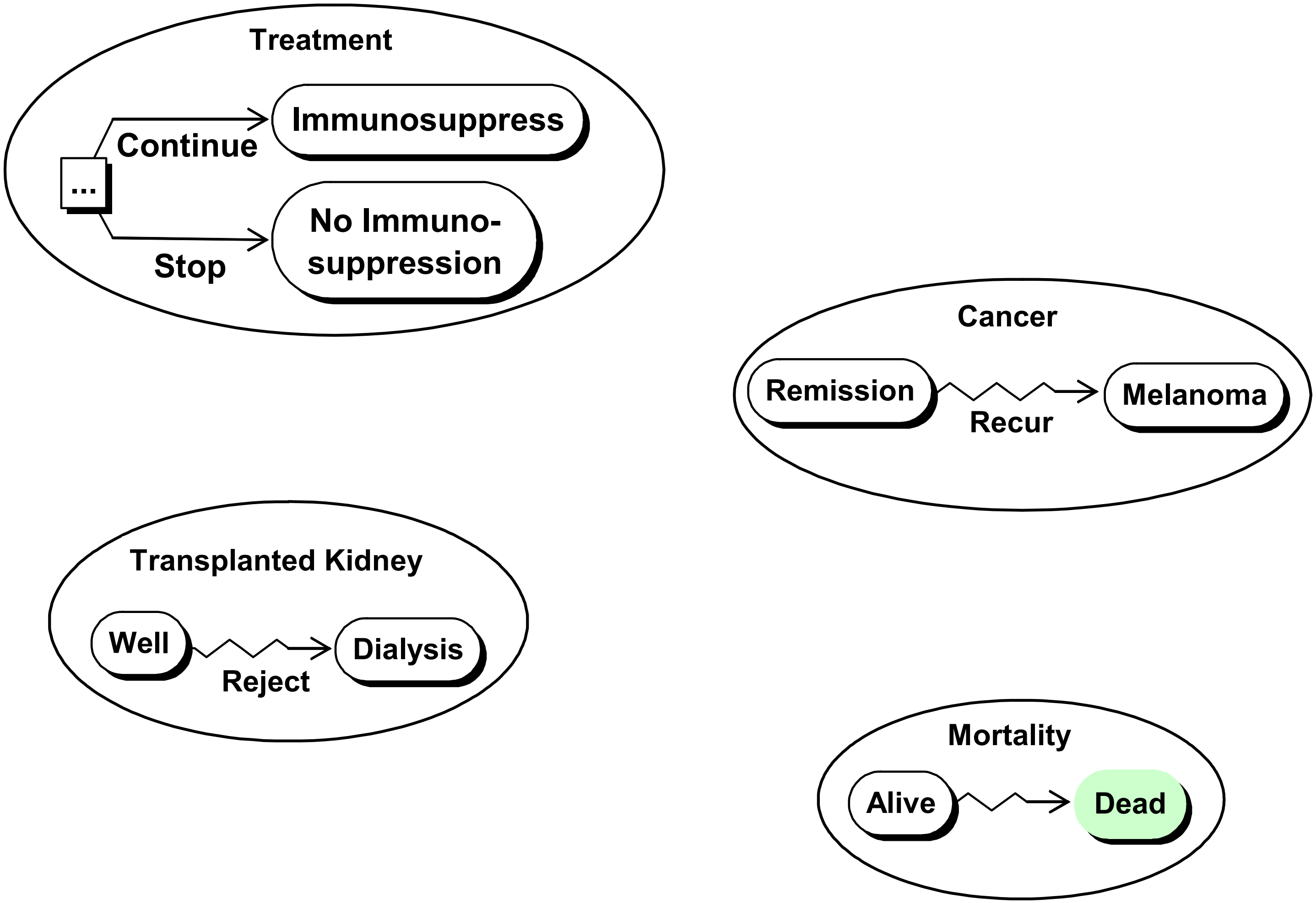


Make sure to include mortality rate dependency

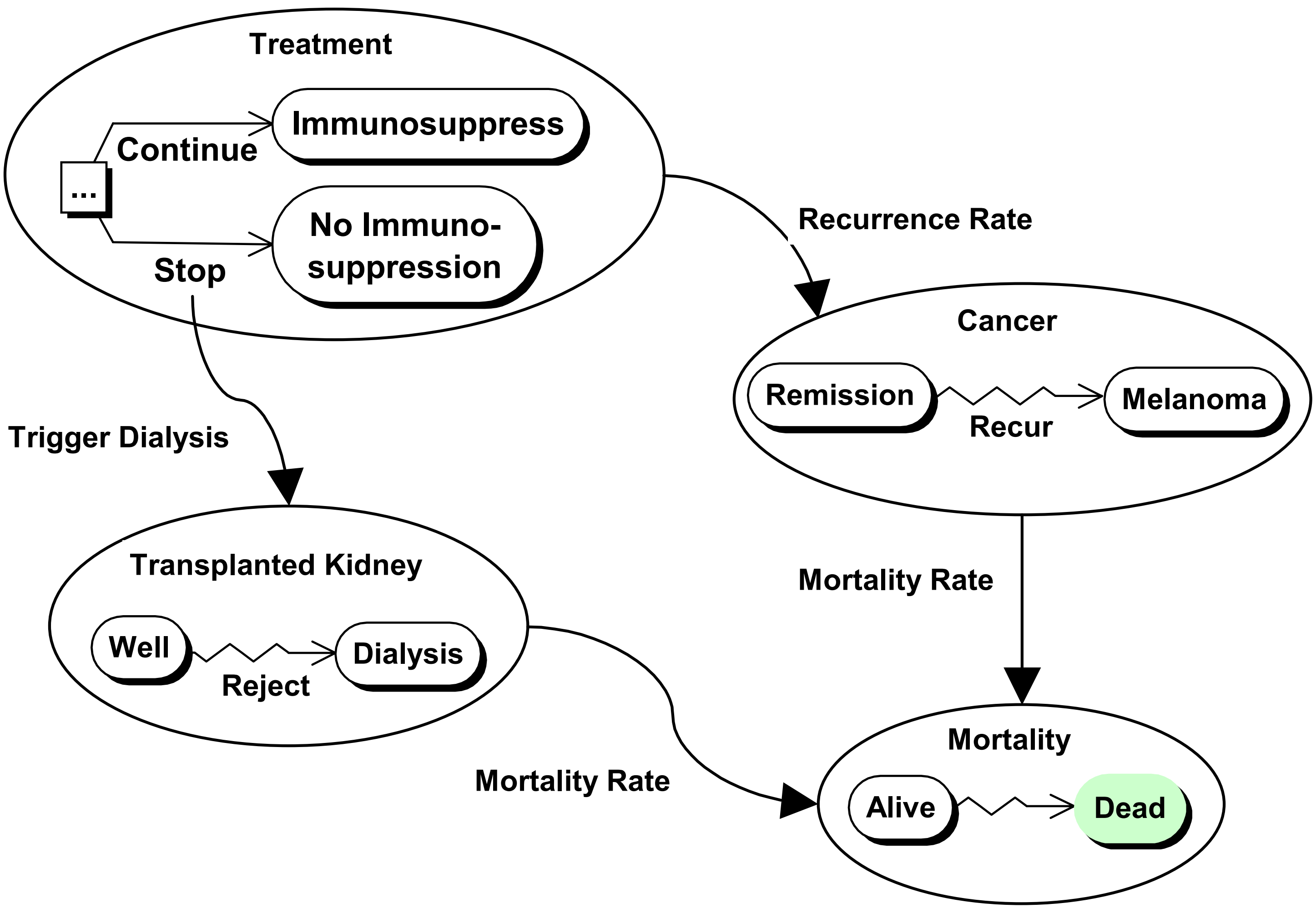
Further factoring...

- There are really four *simultaneous parallel processes* in this model:
  - Mortality
  - Treatment choice
  - Cancer progression
  - Transplant rejection
- Why not factor these out?

…Further factoring



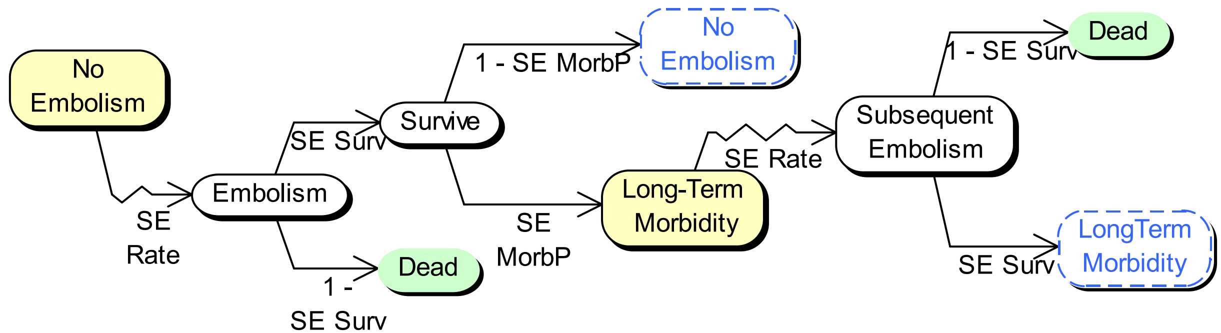
…Further factoring (with dependencies)



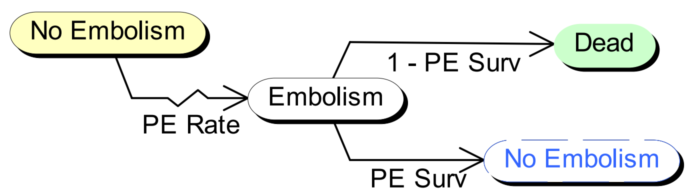
…Factoring stochastic trees

Tsevat et al. (1986): Warfarin for dilated cardiomyopathy

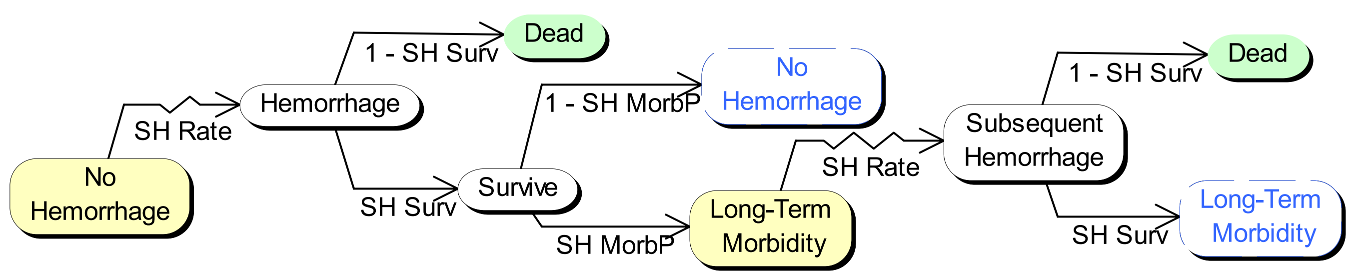
Systemic embolism



Pulmonary embolism



Systemic hemorrhage



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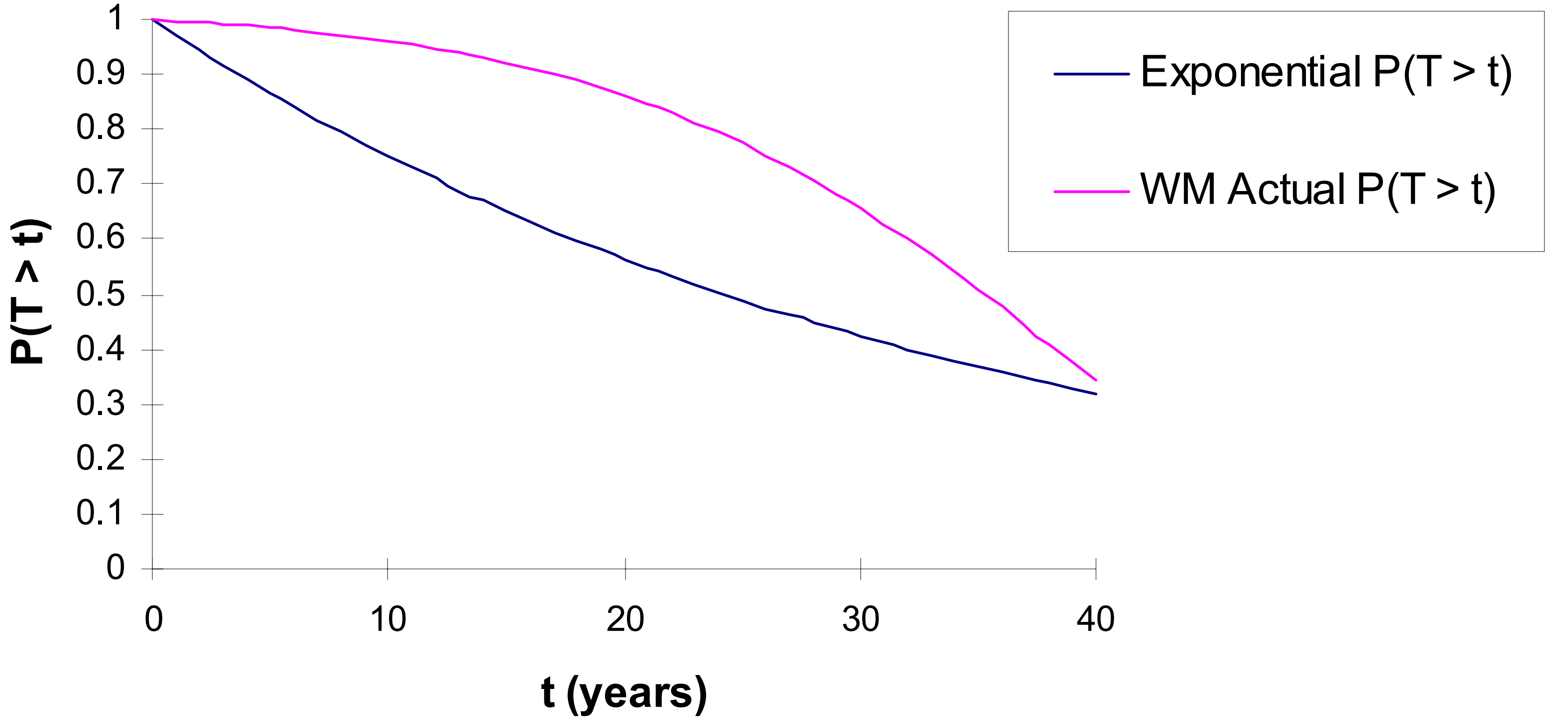
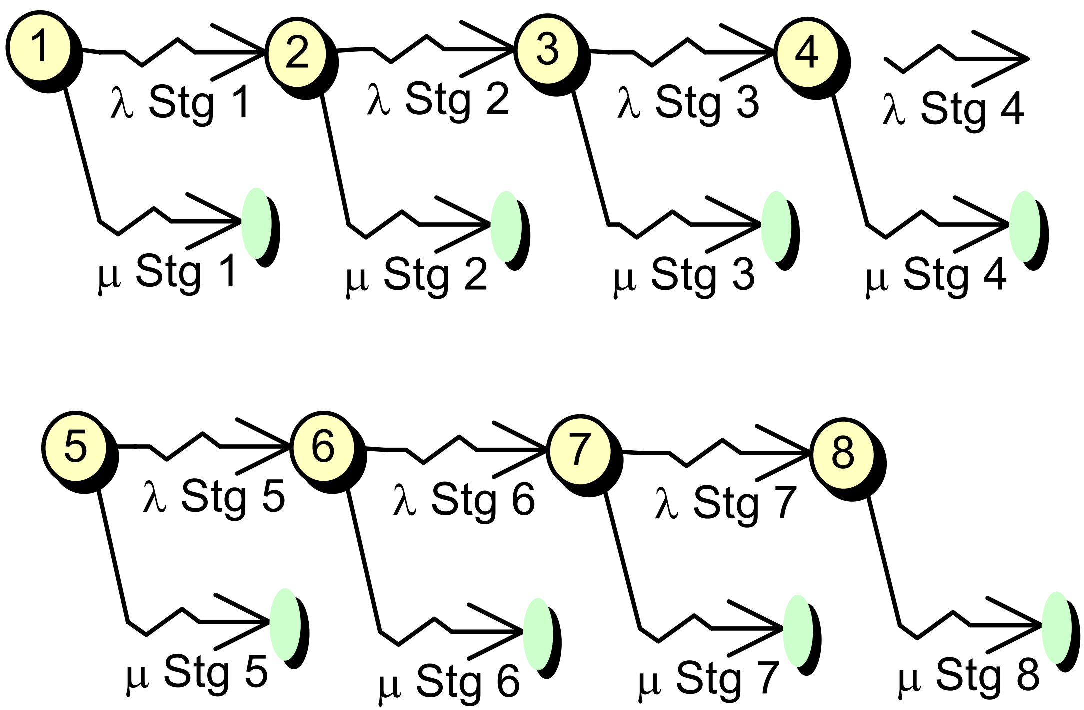
Approximating human survival



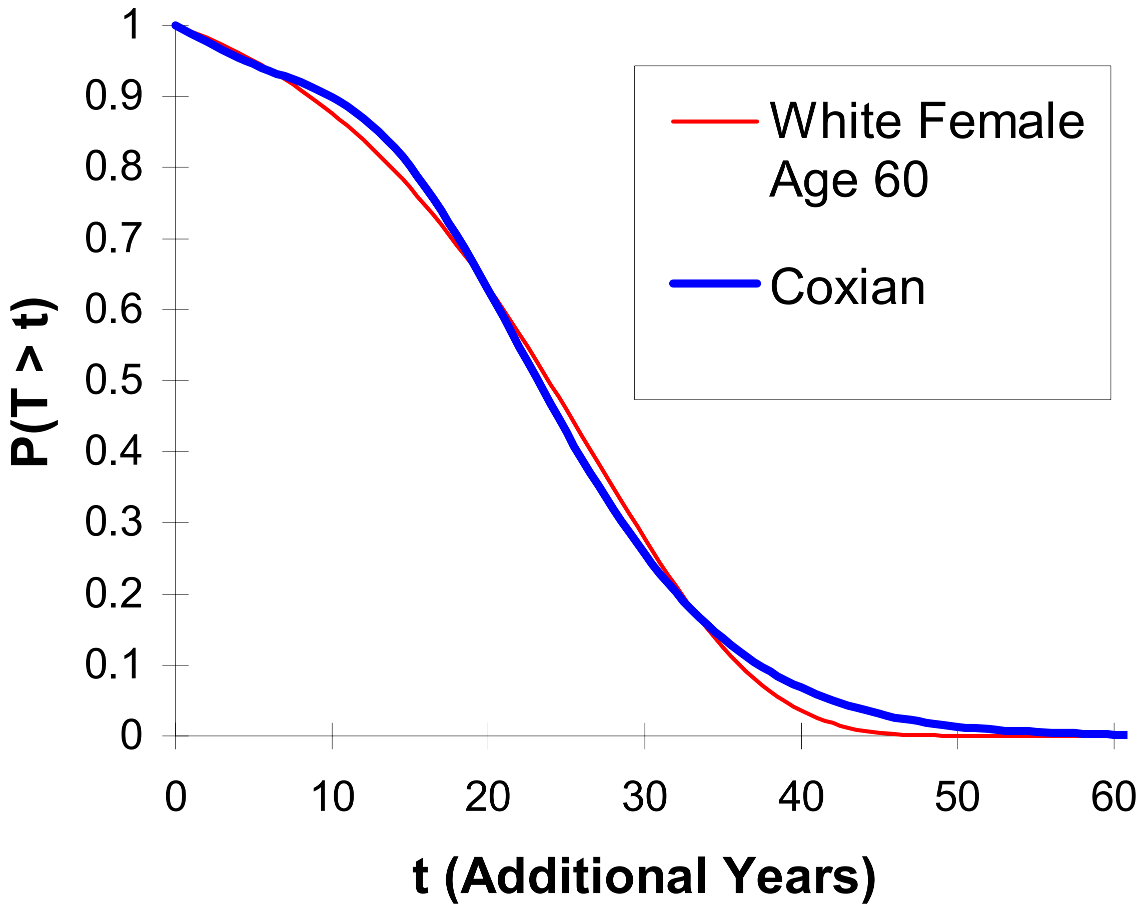
Coxian approximation to human mortality



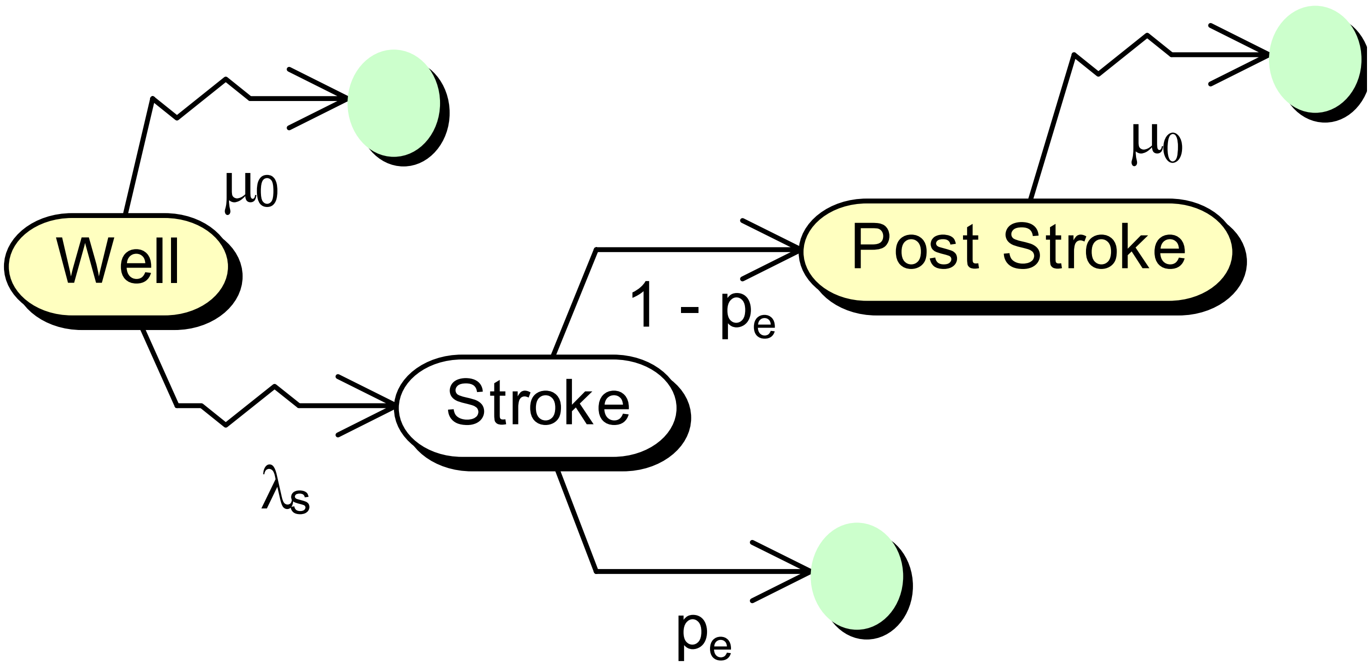
60-year-old white female

	λ	μ
Stg 1	0.29	0.01
Stg 2	0.28	0.02
Stg 3	0.3	0
Stg 4	0.3	0
Stg 5	0.3	0
Stg 6	0.3	0
Stg 7	0.18	0.118
Stg 8		0.298

Coxian approximation to human mortality

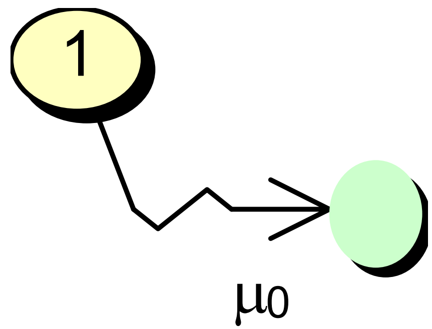


Factoring out mortality

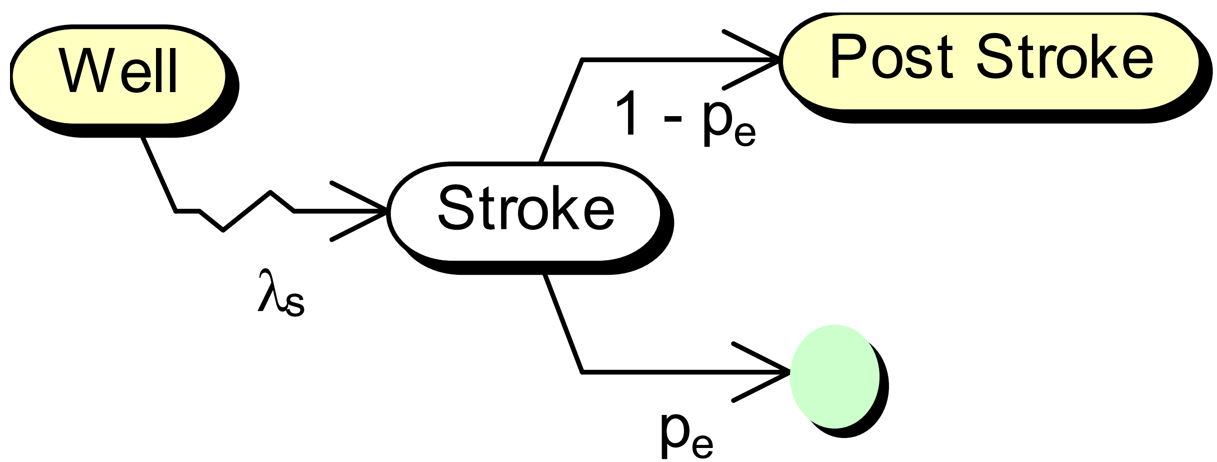


…Factoring out mortality

Background mortality



Stroke morbidity



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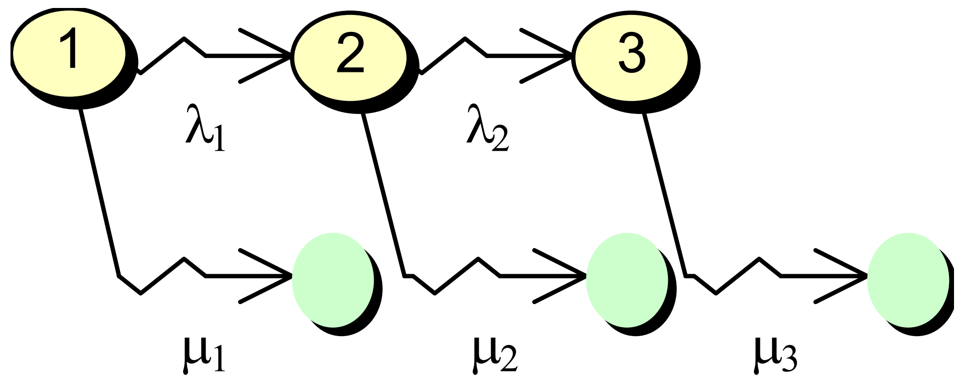
Background mortality



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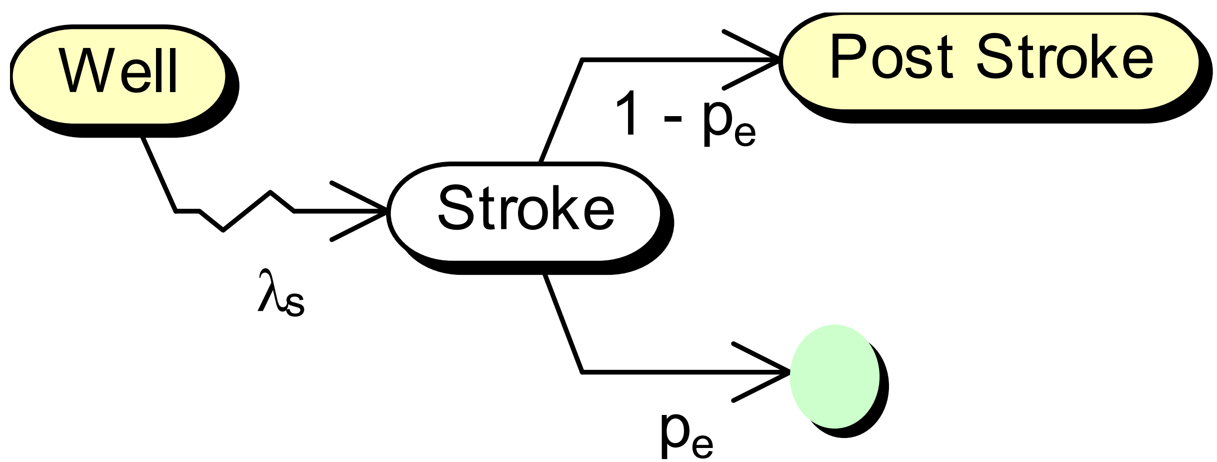

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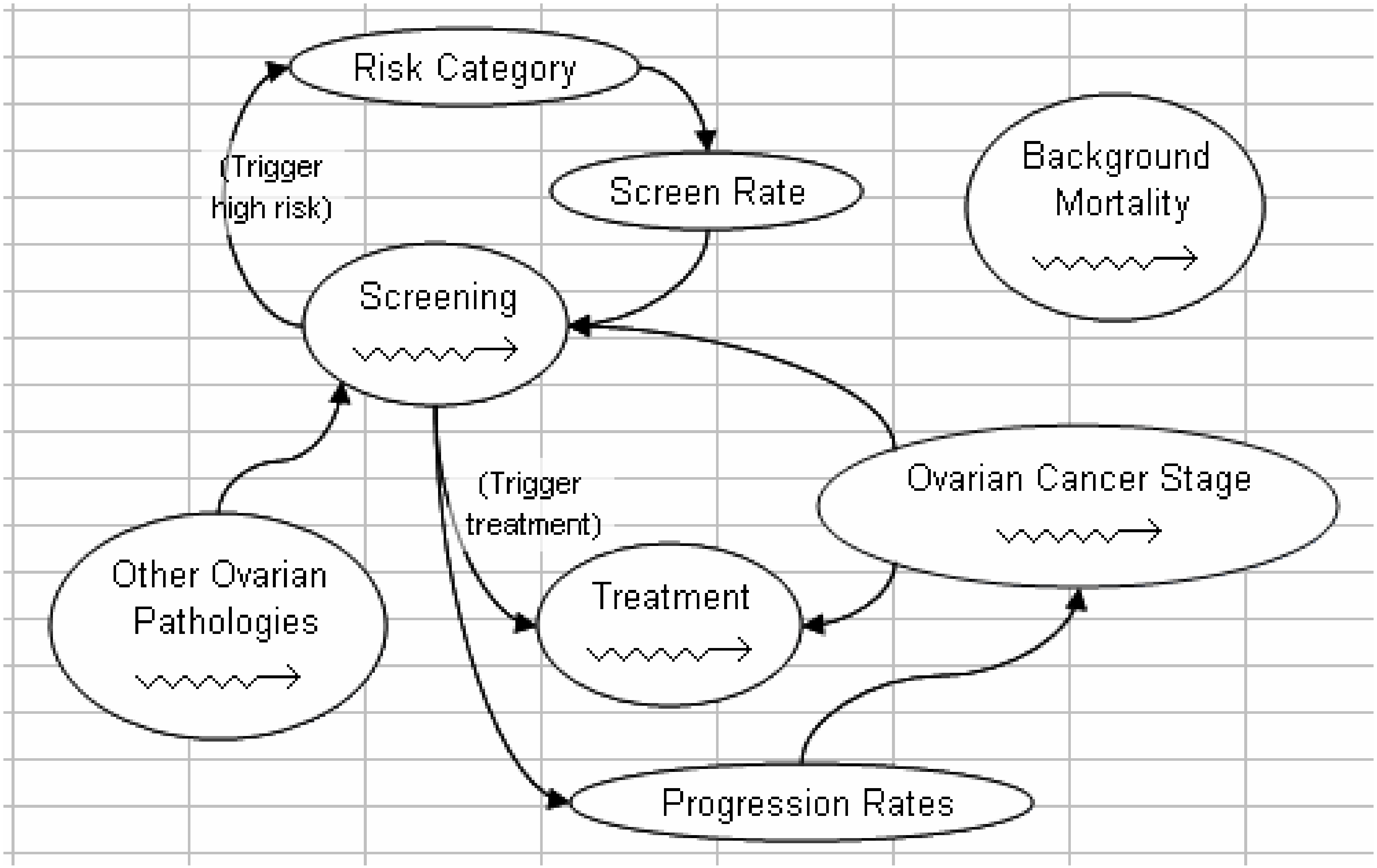
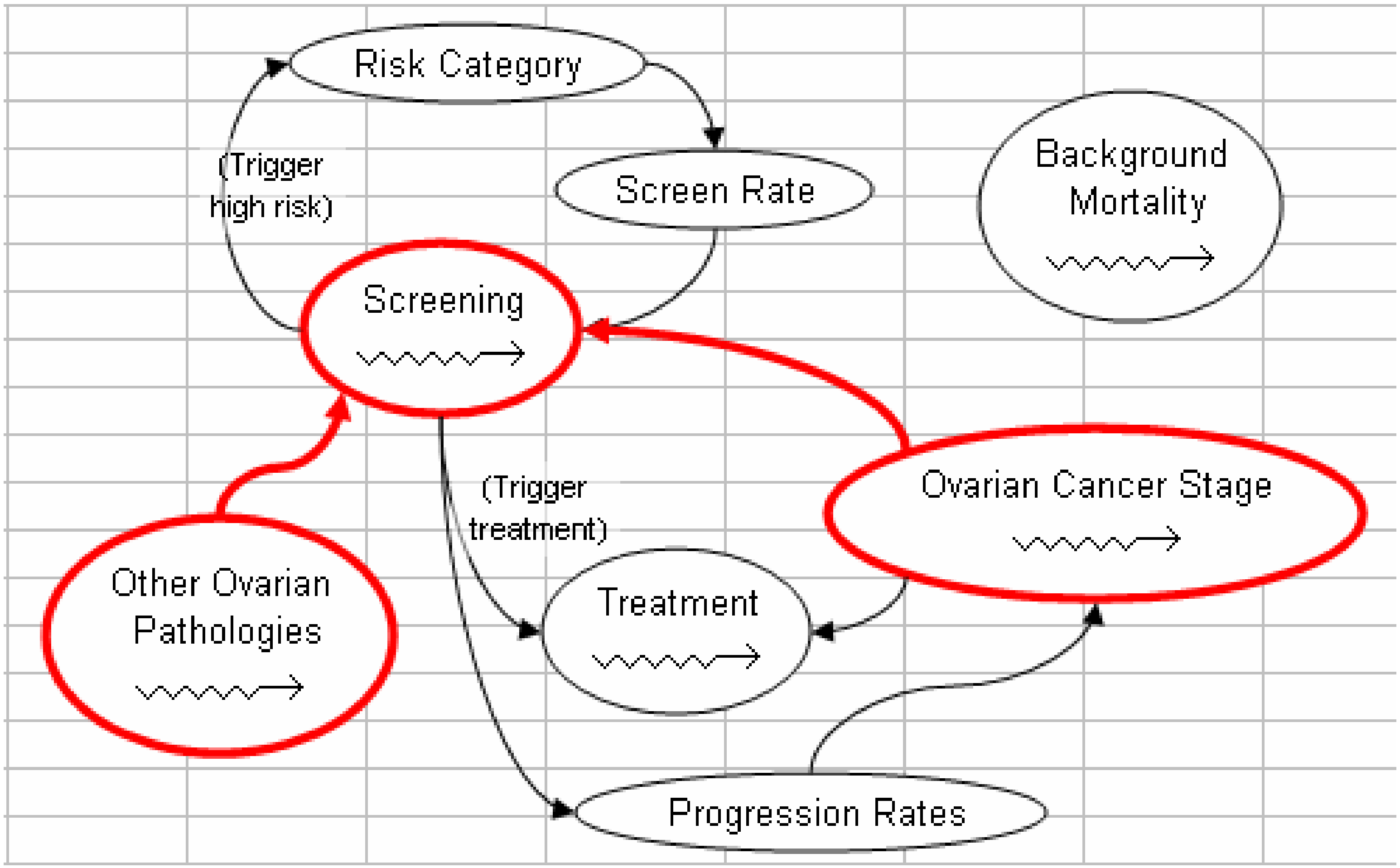
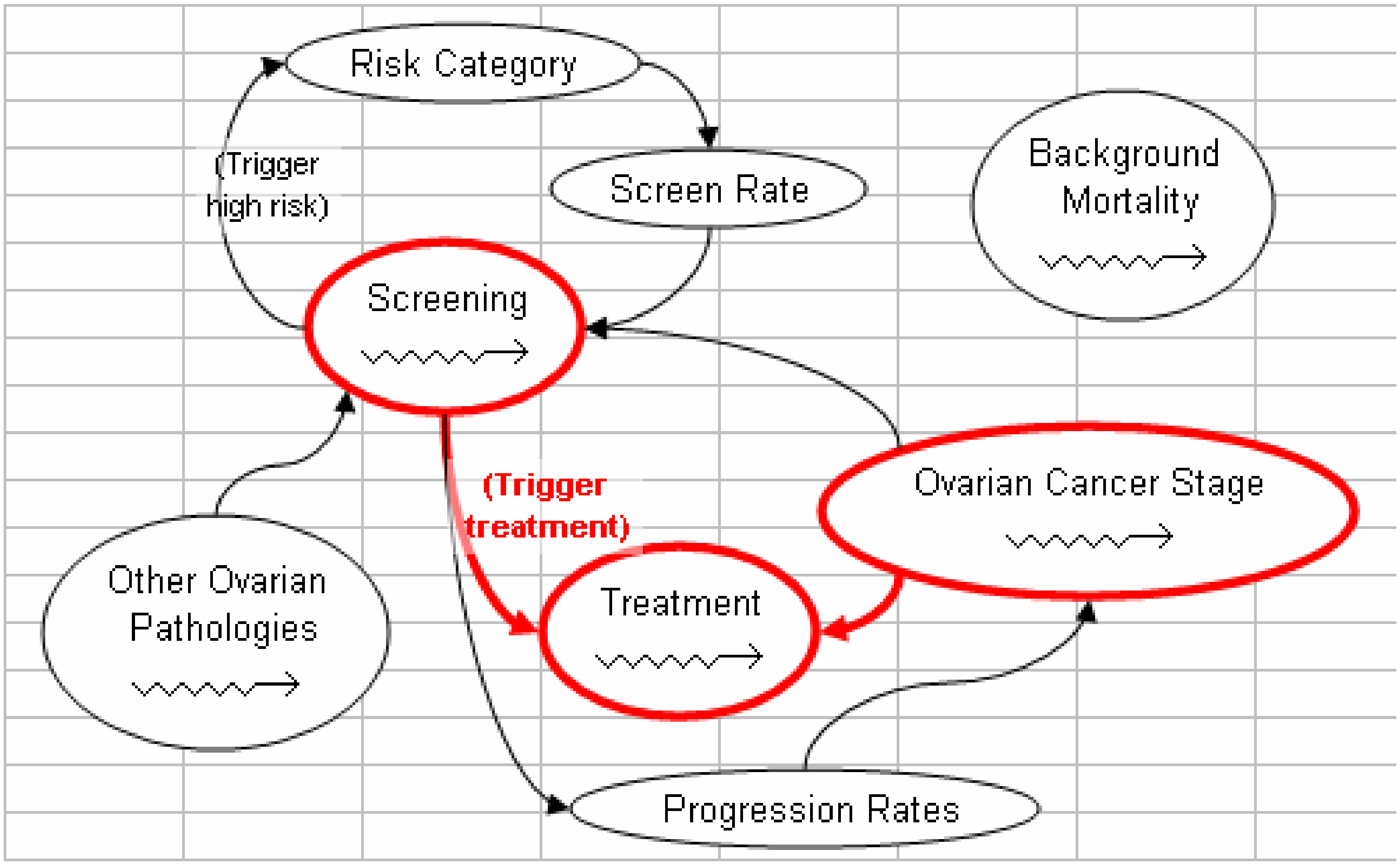
Testing for Ovarian Cancer



Ovarian Cancer Testing : Influence structure



Ovarian Cancer Testing: Influence Structure



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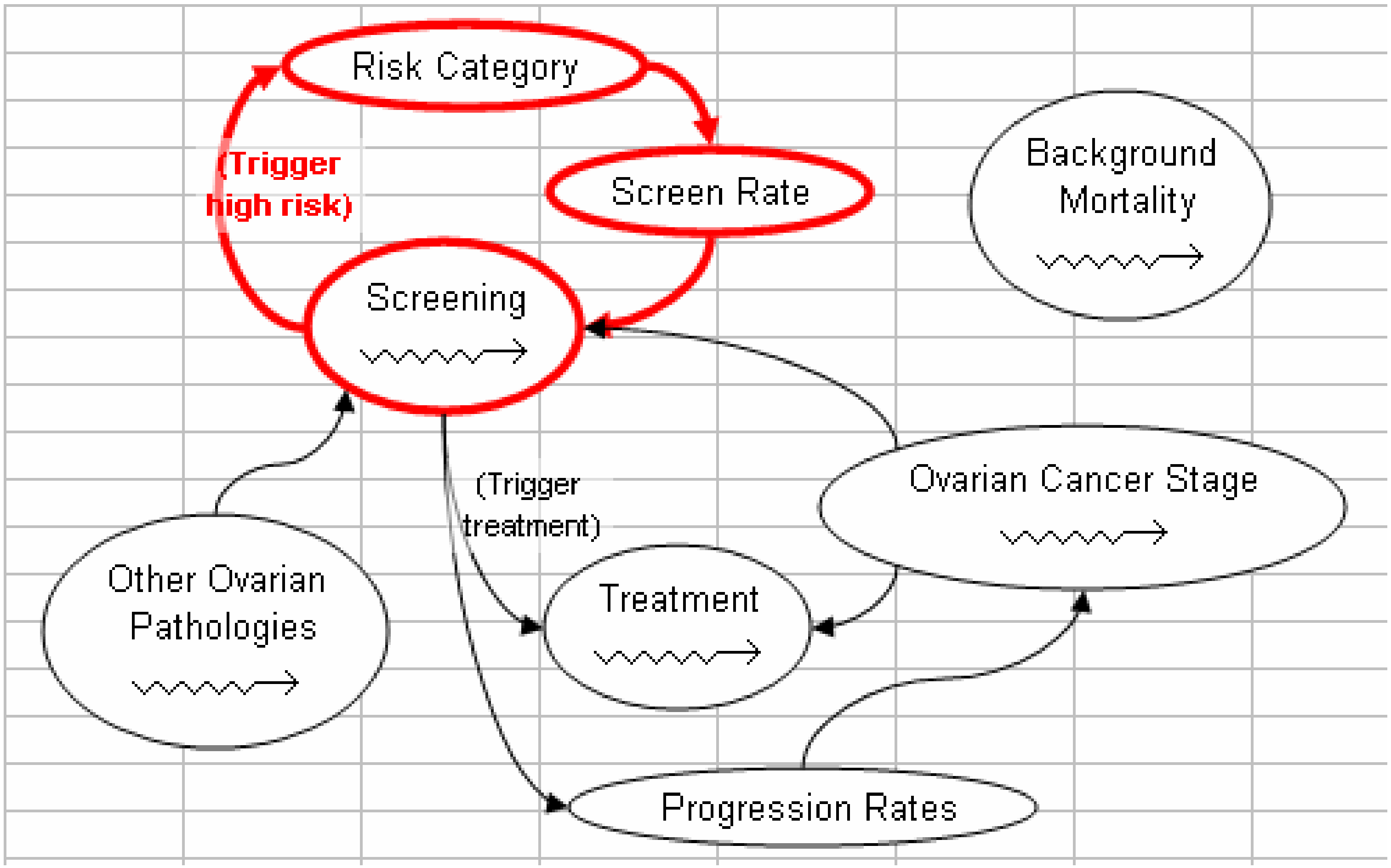
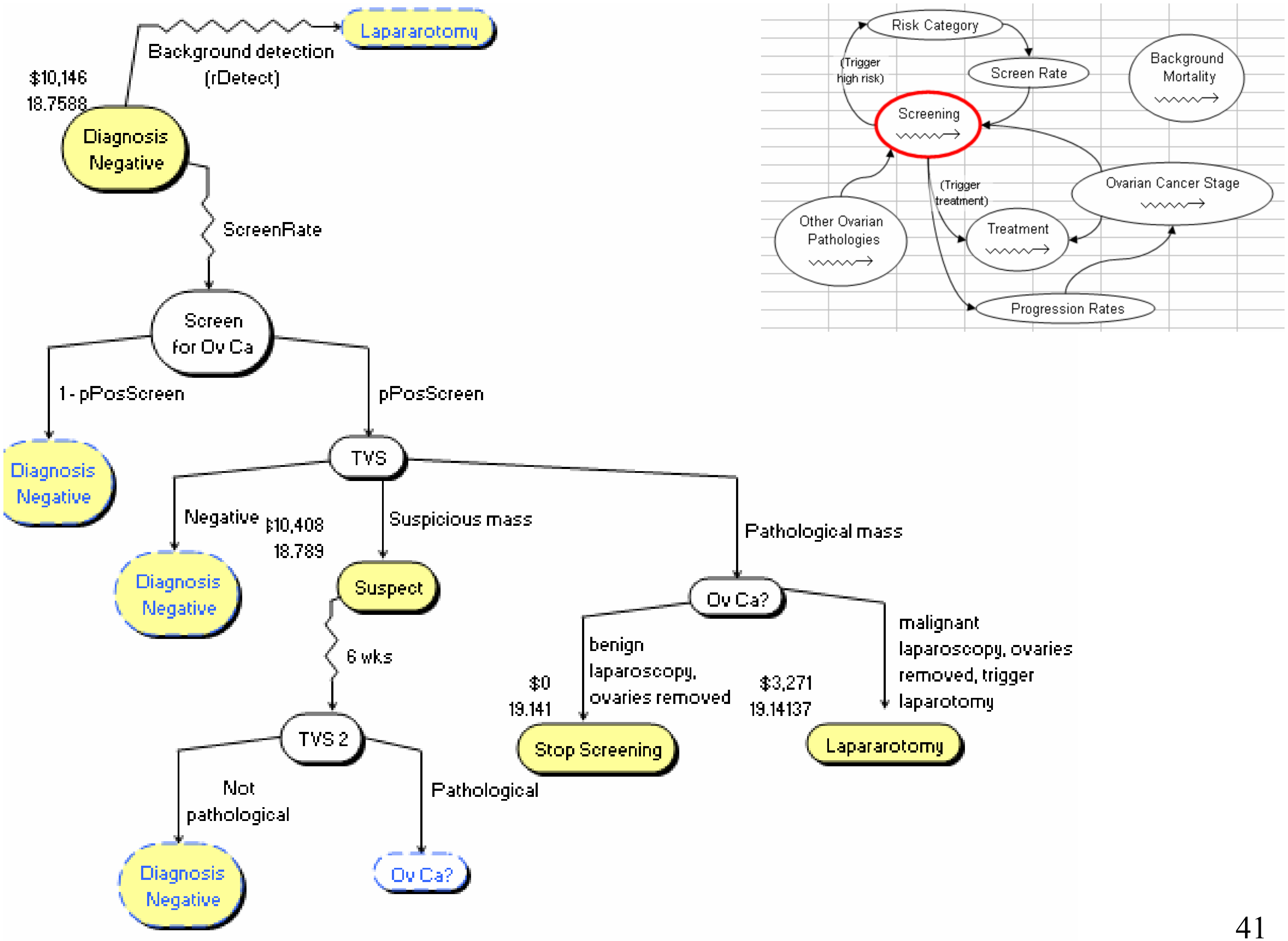
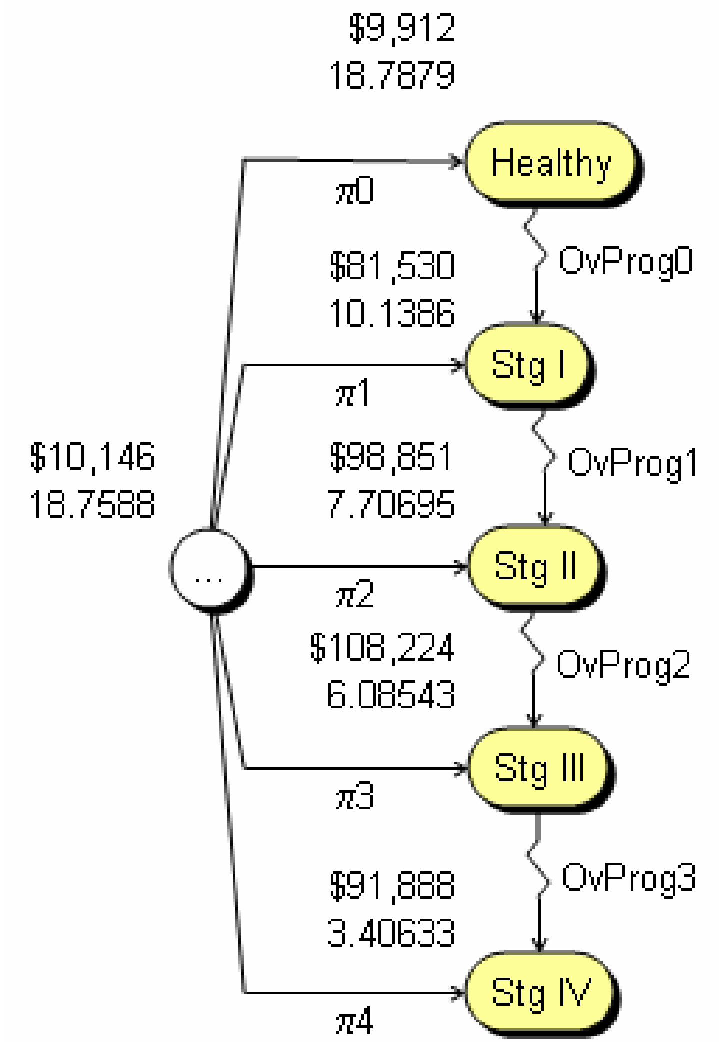
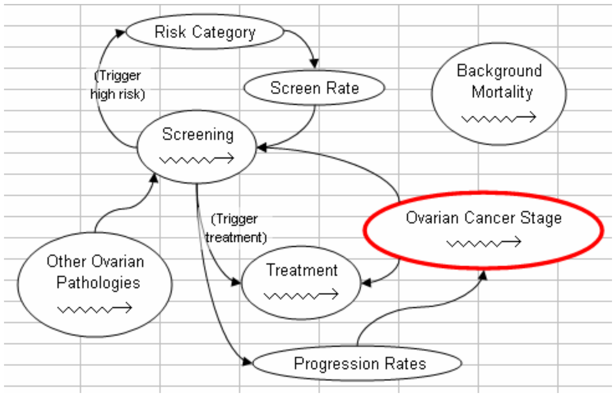


Structure of Screening Factor

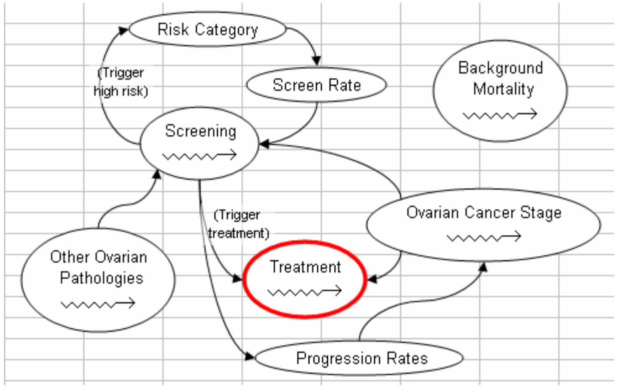


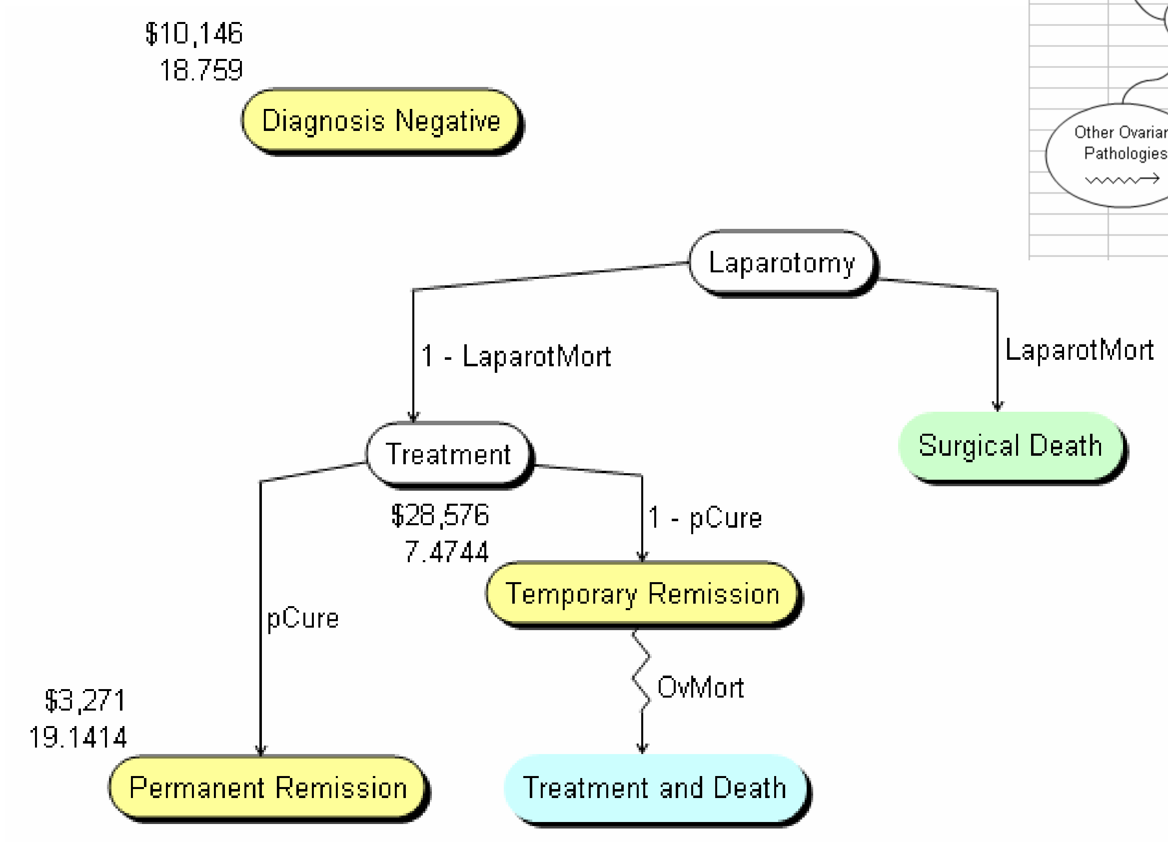
Structure of Ovarian Cancer Stage Factor



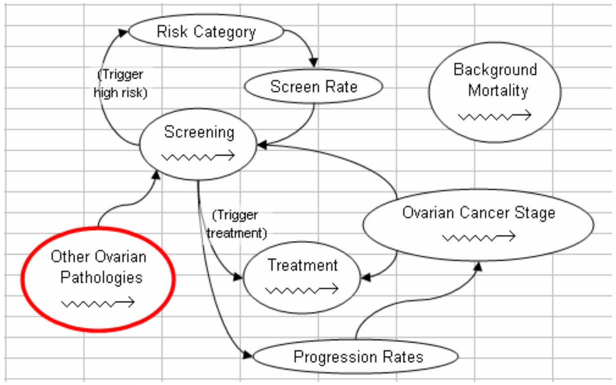


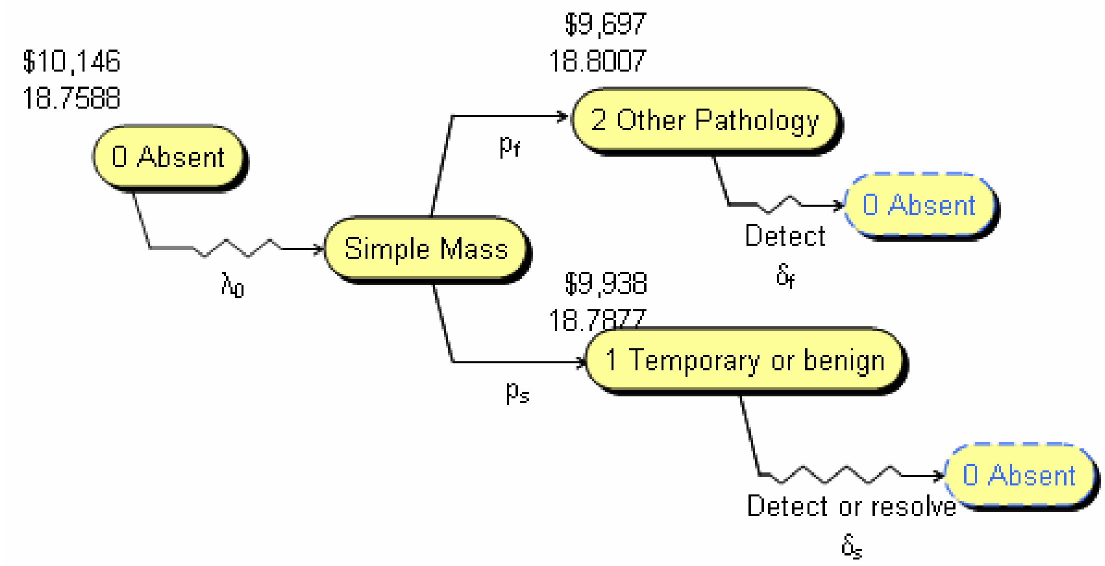
Structure of Treatment Factor





Structure of Other Ovarian Pathologies Factor





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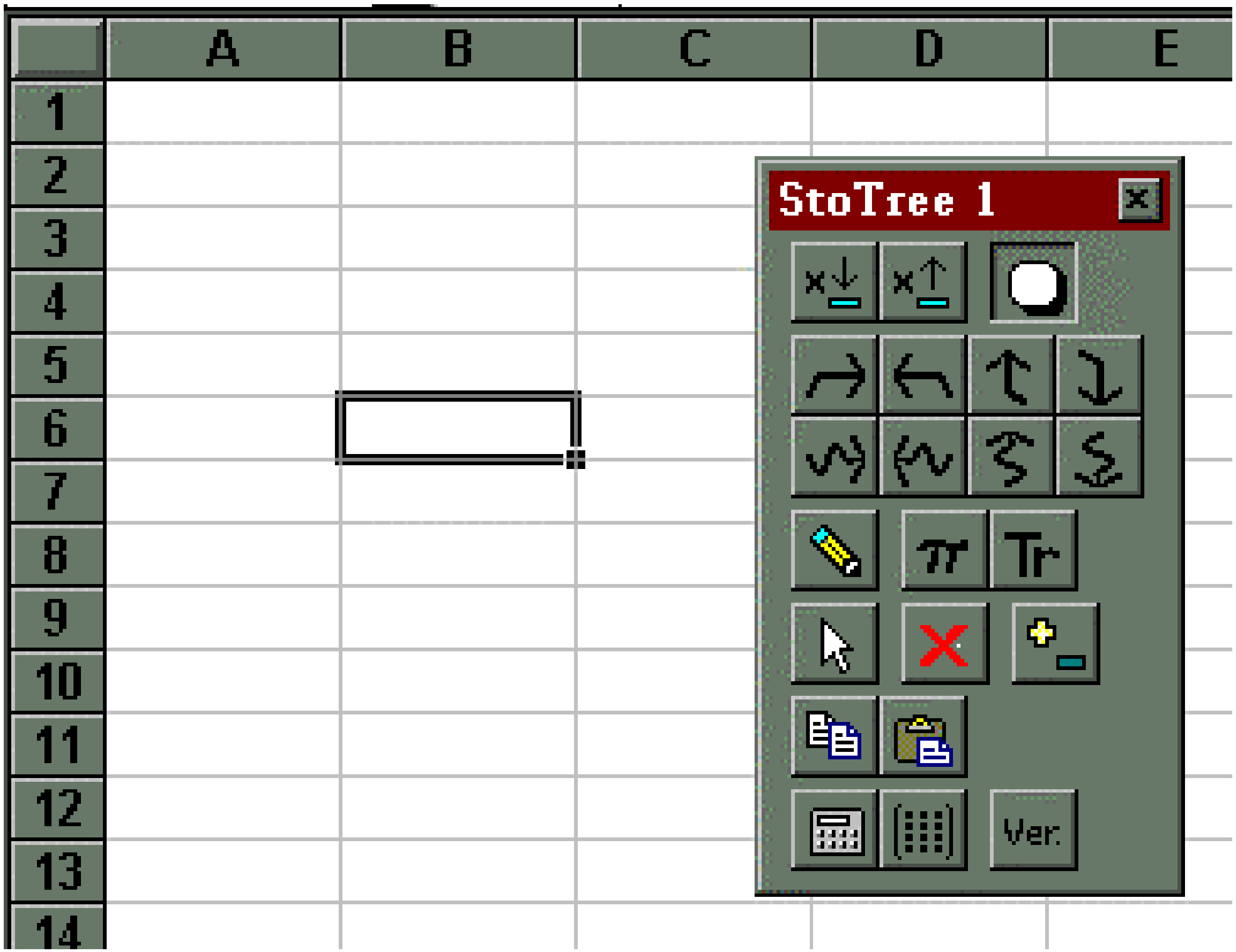
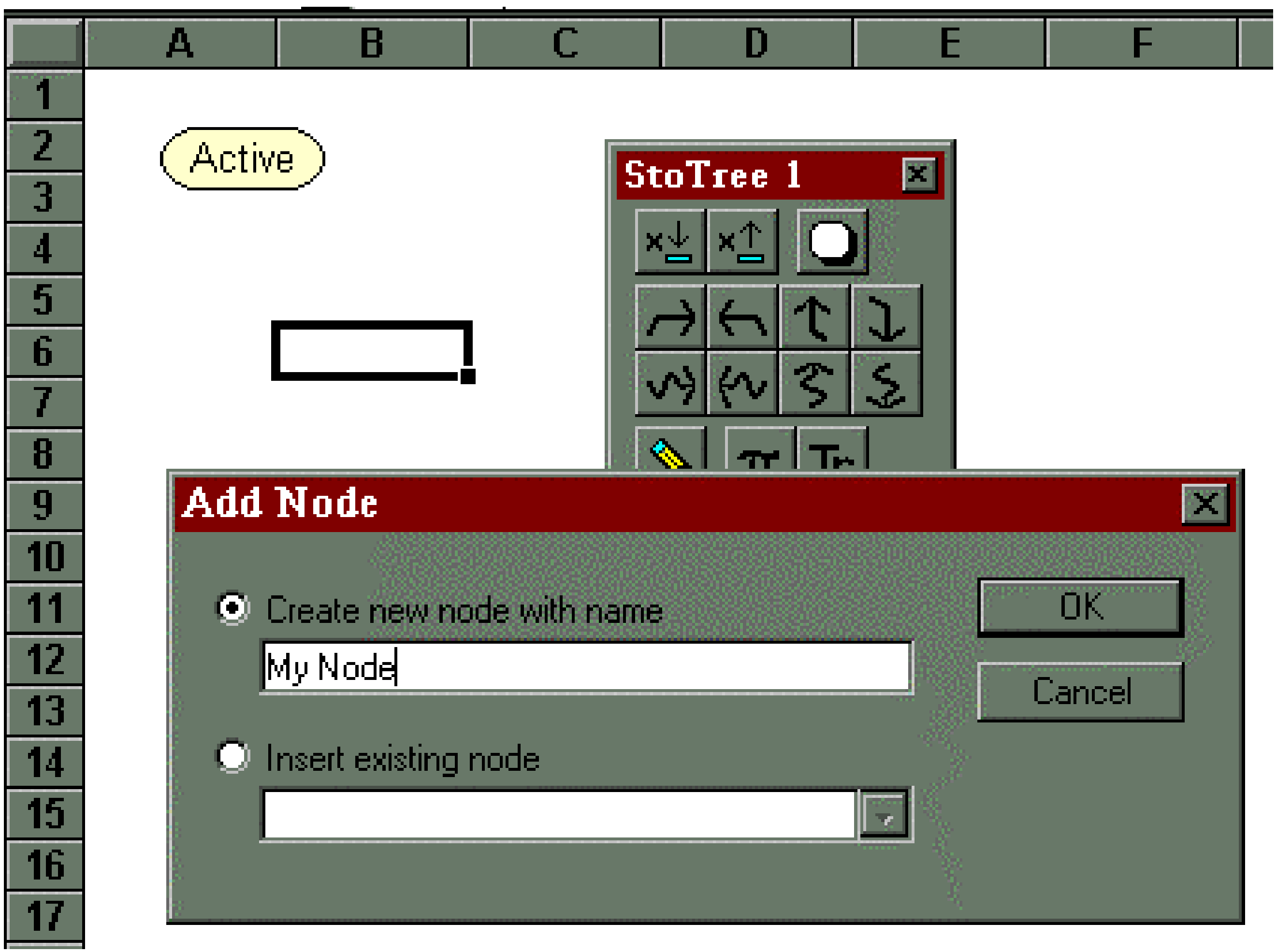
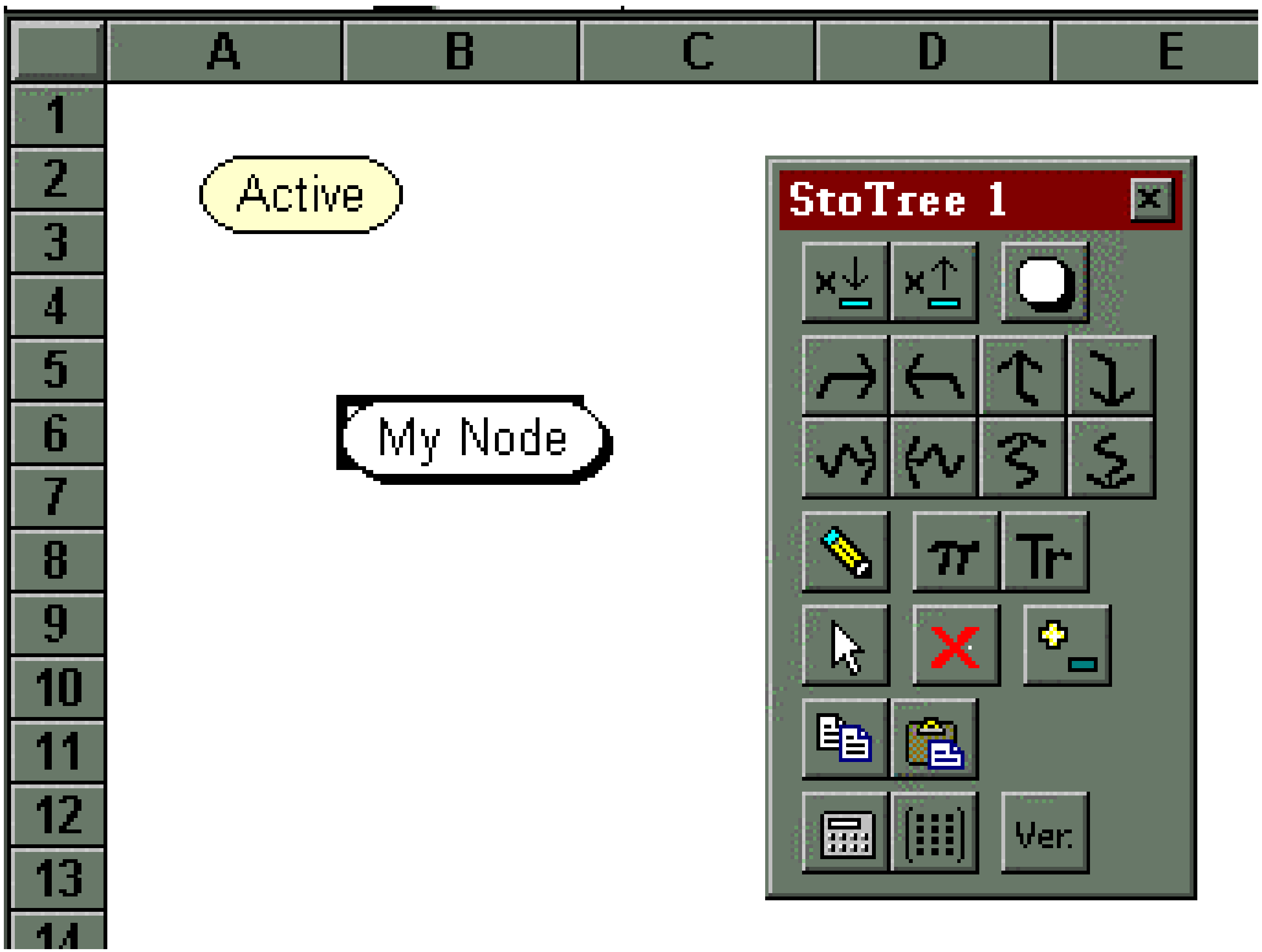
The StoTree modeling environment



The StoTree modeling environment



…StoTree modeling environment



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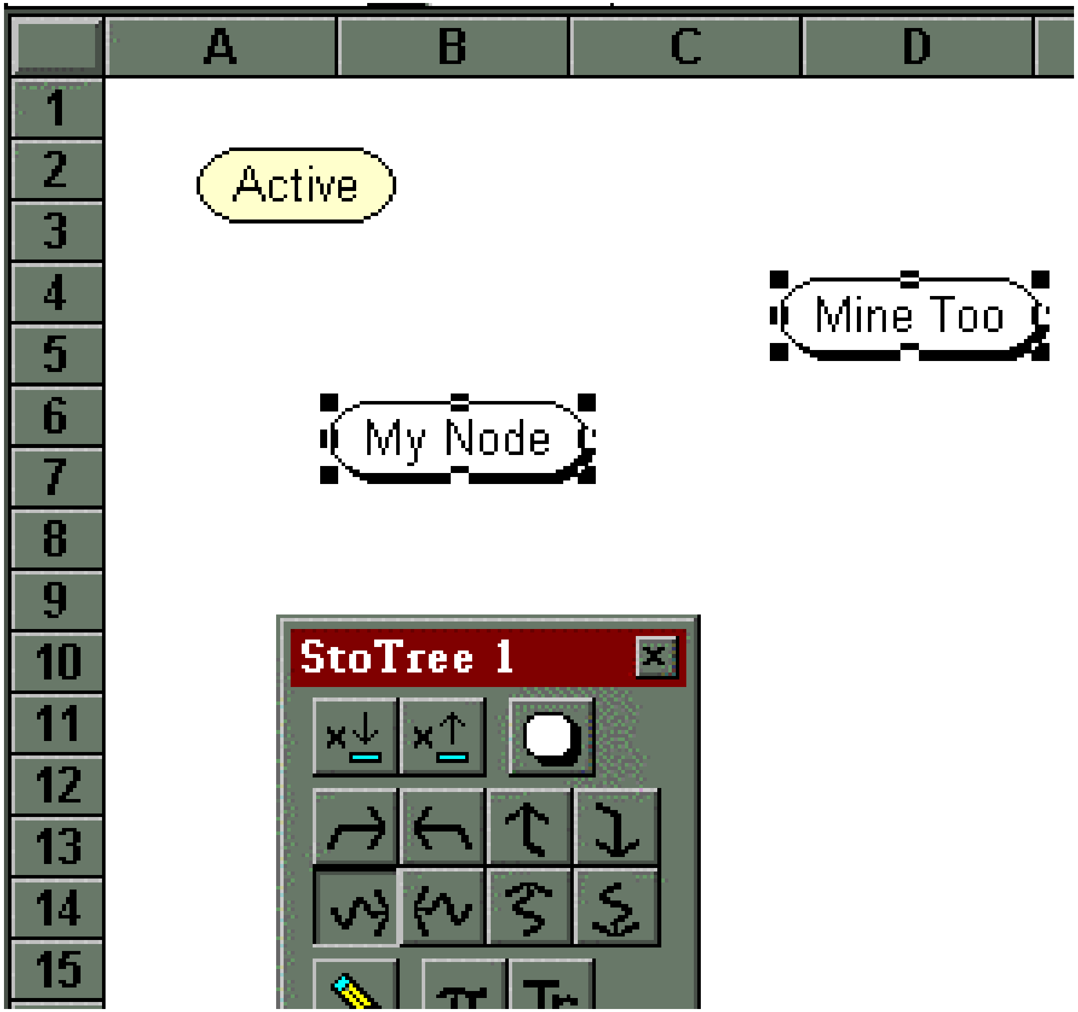

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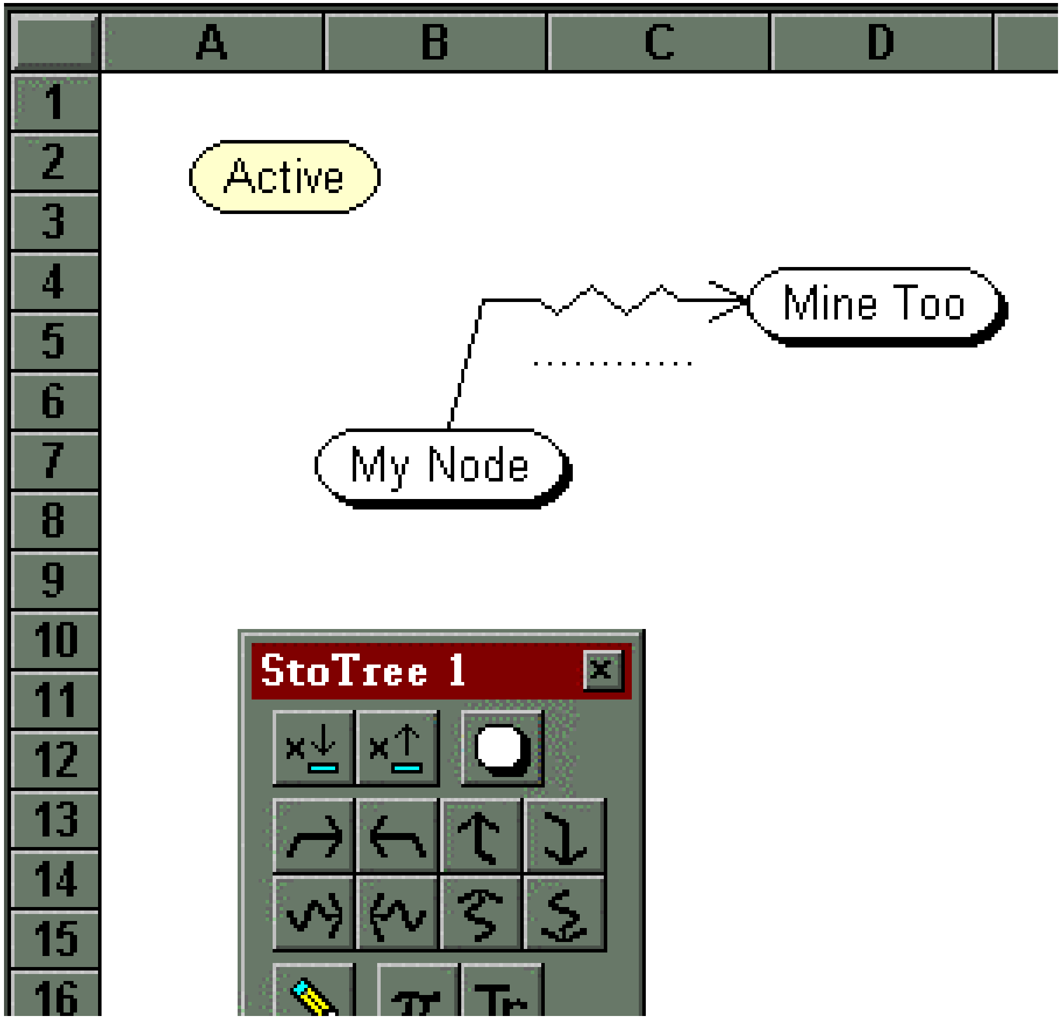
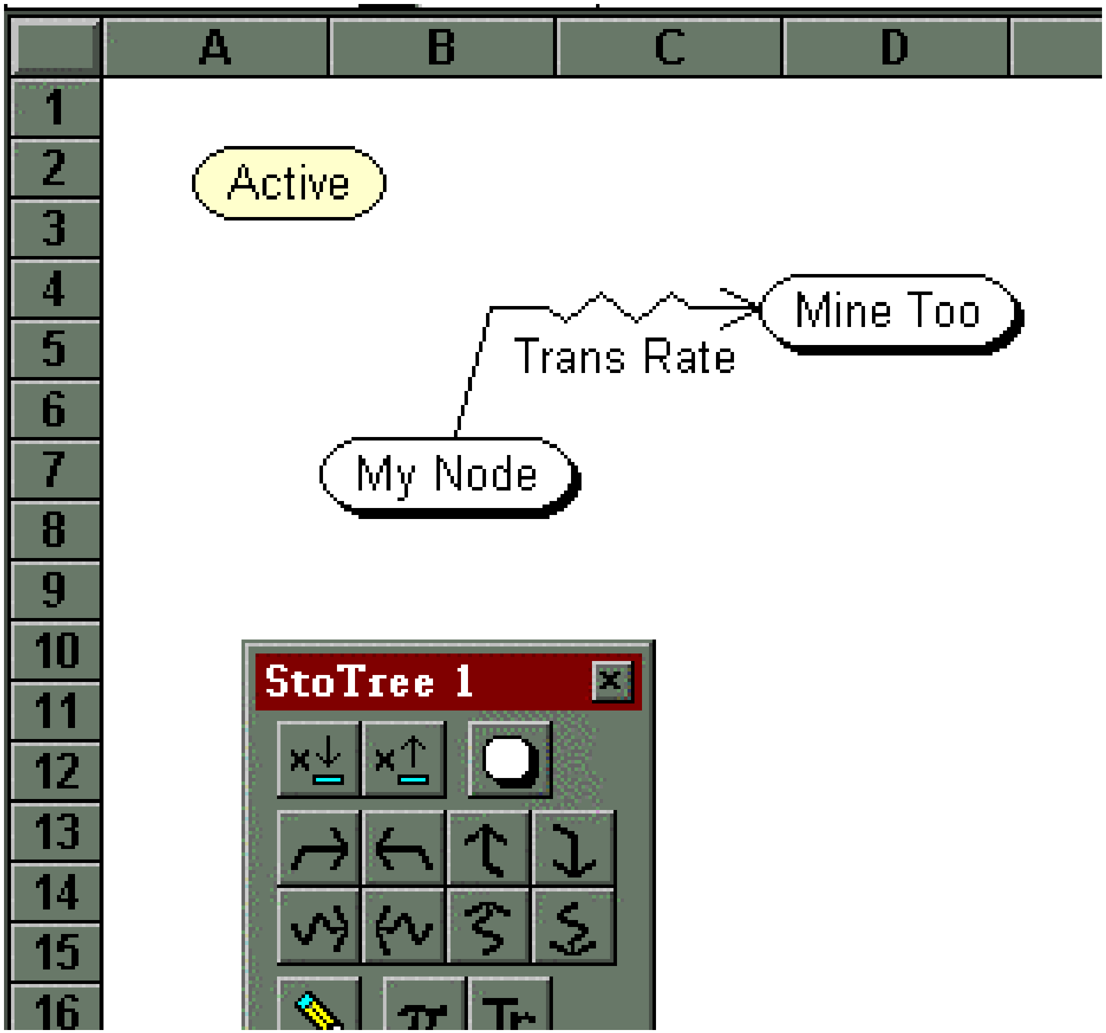


...StoTree modeling environment



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Cost-Effectiveness for Ovarian Cancer Testing

- Hypothetical test for ovarian cancer
- High-risk women (e.g., close relative with breast or ovarian cancer): 8% lifetime risk
- Sensitivity 75% for Stages 1,2; 85% for stages 3,4
- Specificity 97%

Cost-Effectiveness Results for Ovarian Cancer Testing

Screen frequency	0	4 yr.	2 yr.	1 yr.	6 mo.
Cost ($)	$4,440	$5,883	$7,316	$10,147	$15,662
Effectiveness (years)	18.72	18.73	18.74	18.76	18.78
ΔC		$1,443	$1,433	$2,831	$5,515
ΔE (days)		4.44	3.55	5.23	6.13
ΔE (days) vs no screening		4.44	7.99	13.22	19.35
ΔC/ΔE ($/life year)		$118,690	$147,443	$197,674	$328,411
ΔC/ΔE ($/life year) vs no screening		$118,690	$131,462	$157,660	$211,773

Current and Past Projects

- Total hip replacement (with Rowland Chang, James Pellissier)
- DCIS - Ductal carcinoma in situ (with Monica Morrow)
- Ovarian cancer screening (with Debbie Dobrez, Elizabeth Calhoun)

Questions?