

# Factored stochastic tree modeling for medical decision making

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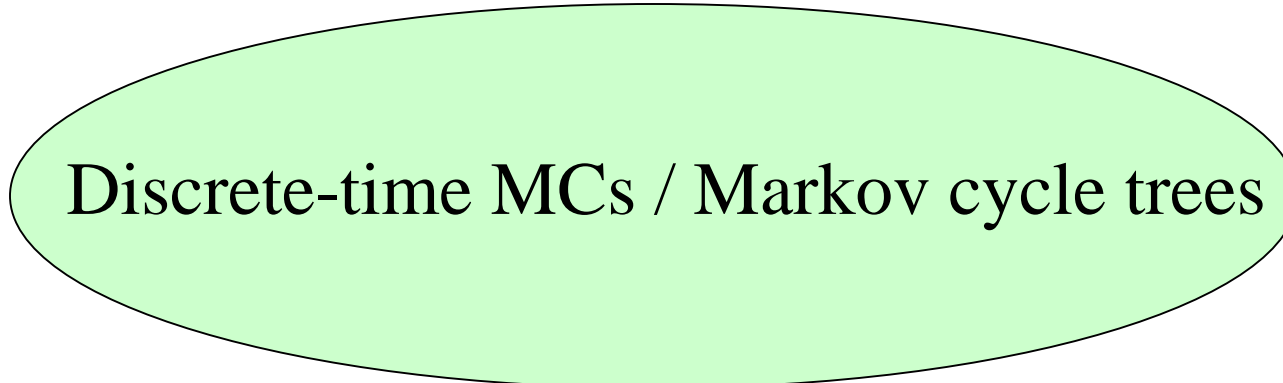
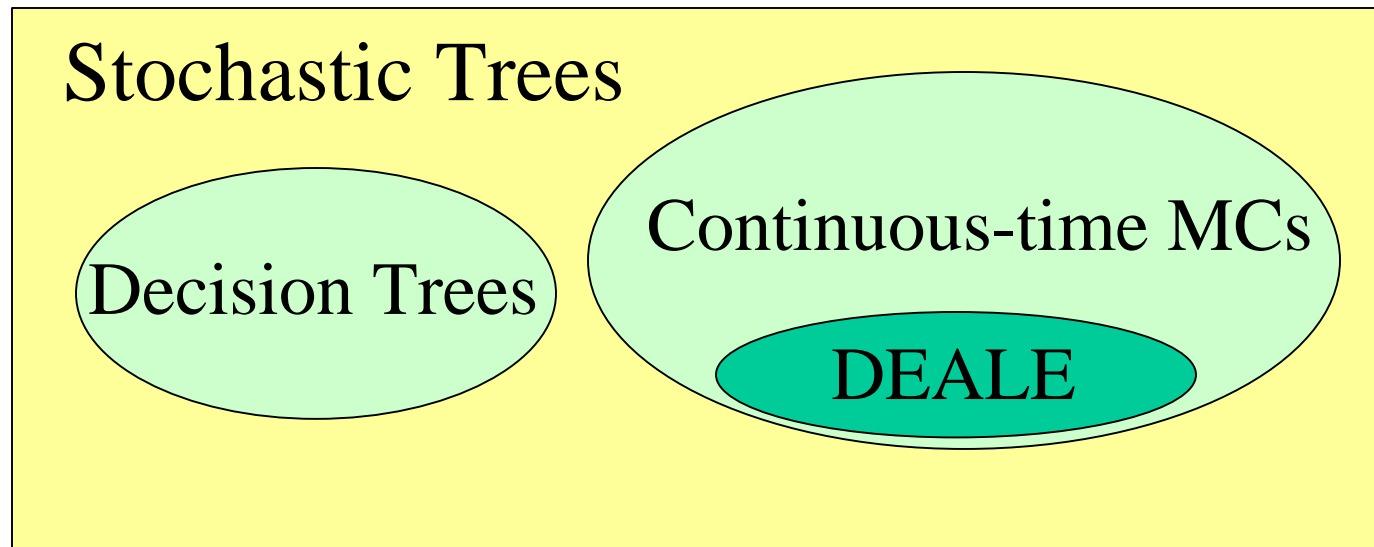
## Outline of talk

- What is a stochastic tree?
  - Basic concepts
  - Stochastic tree rollback
- Factoring stochastic trees
- Approximating human mortality
- Our THA model
- The StoTree modeling environment
- Cost-effectiveness for THA

## 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?

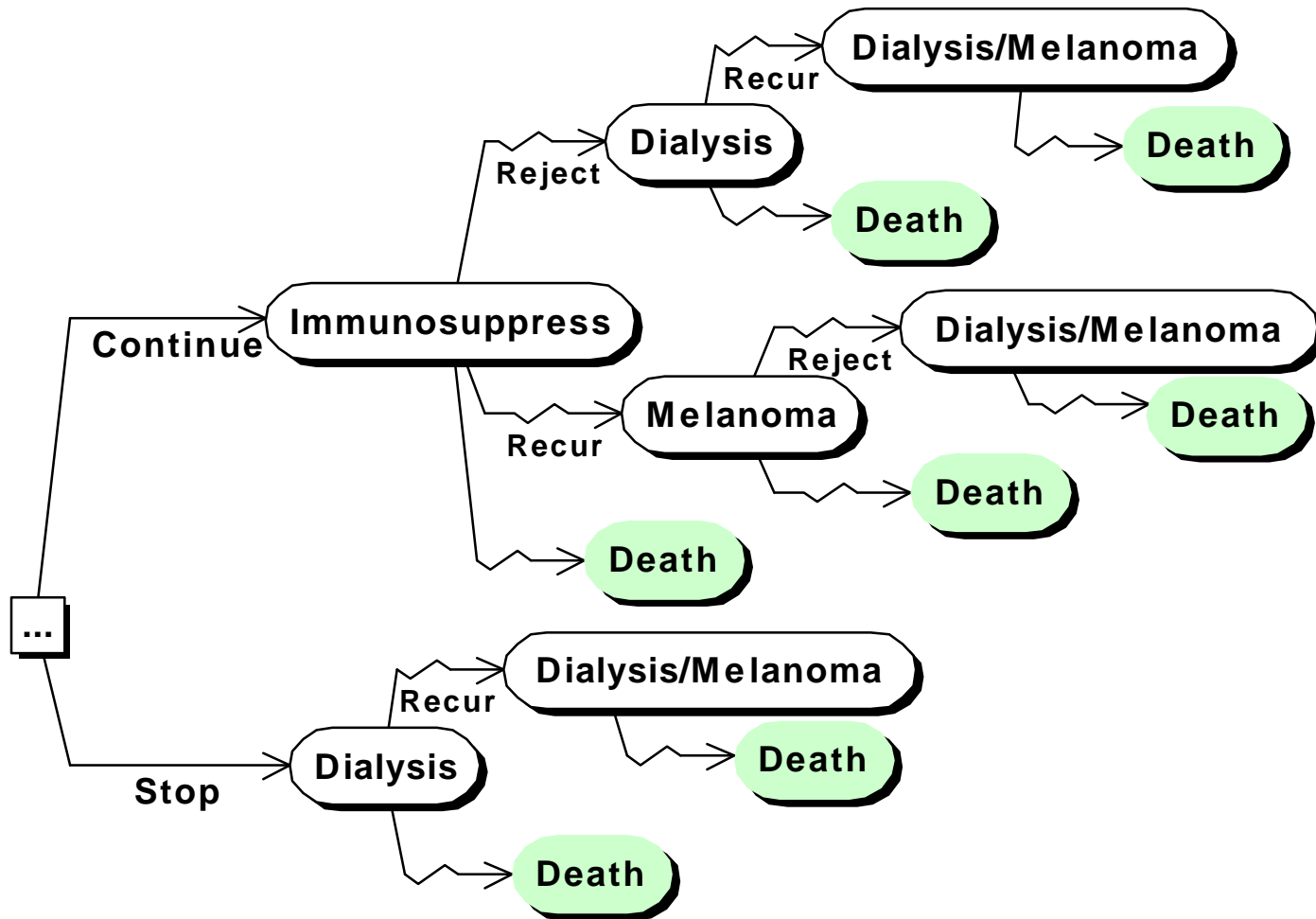
- Beck and Sonnenberg (1993):
  - 42-year old man received kidney transplant 18 months ago. Normal kidney function maintained under immunosuppressive therapy .
  - Two synchronous melanomas appeared and required wide resection.

... What is a stochastic tree?

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

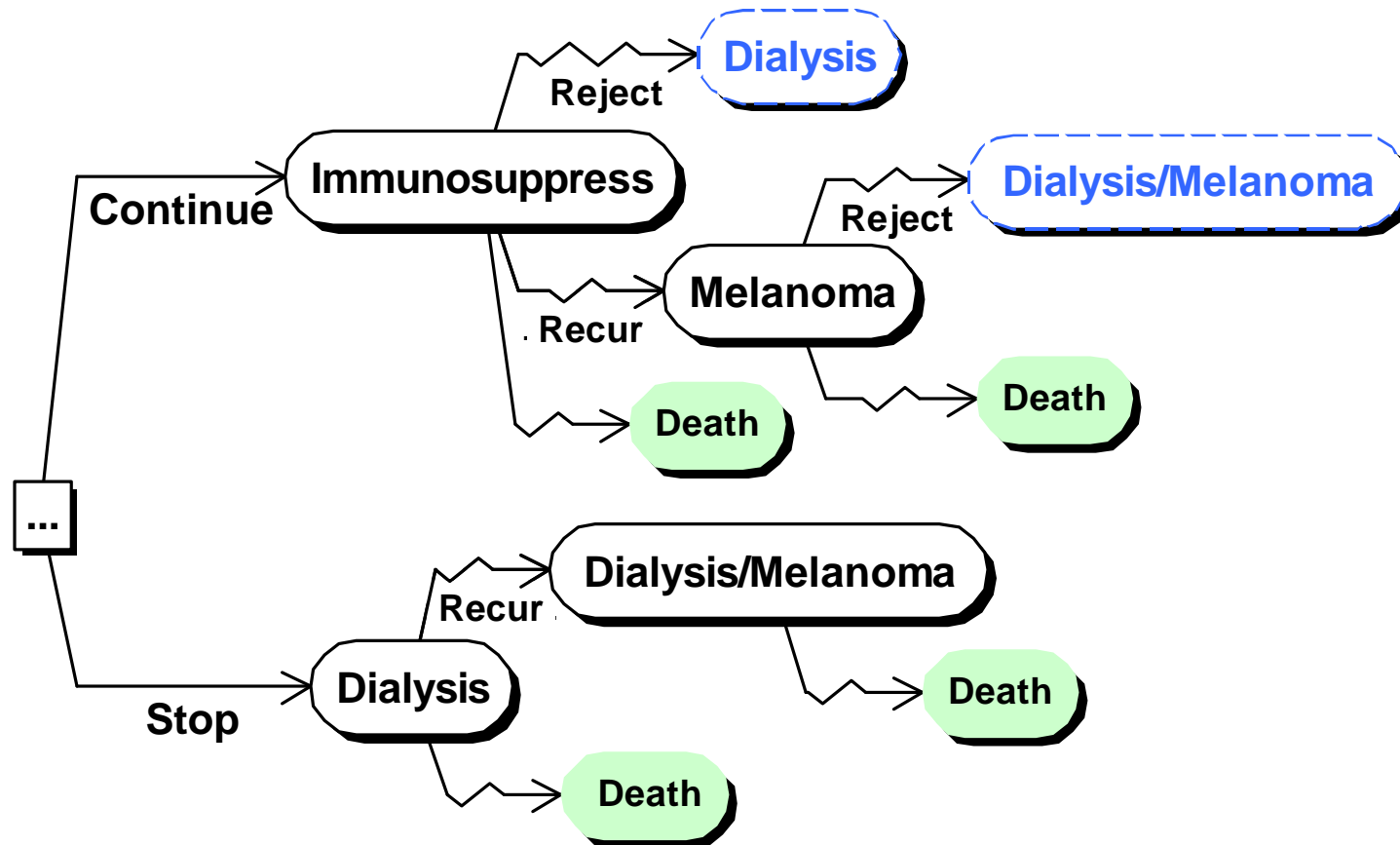
# ...What is a stochastic tree?

Stochastic tree representation

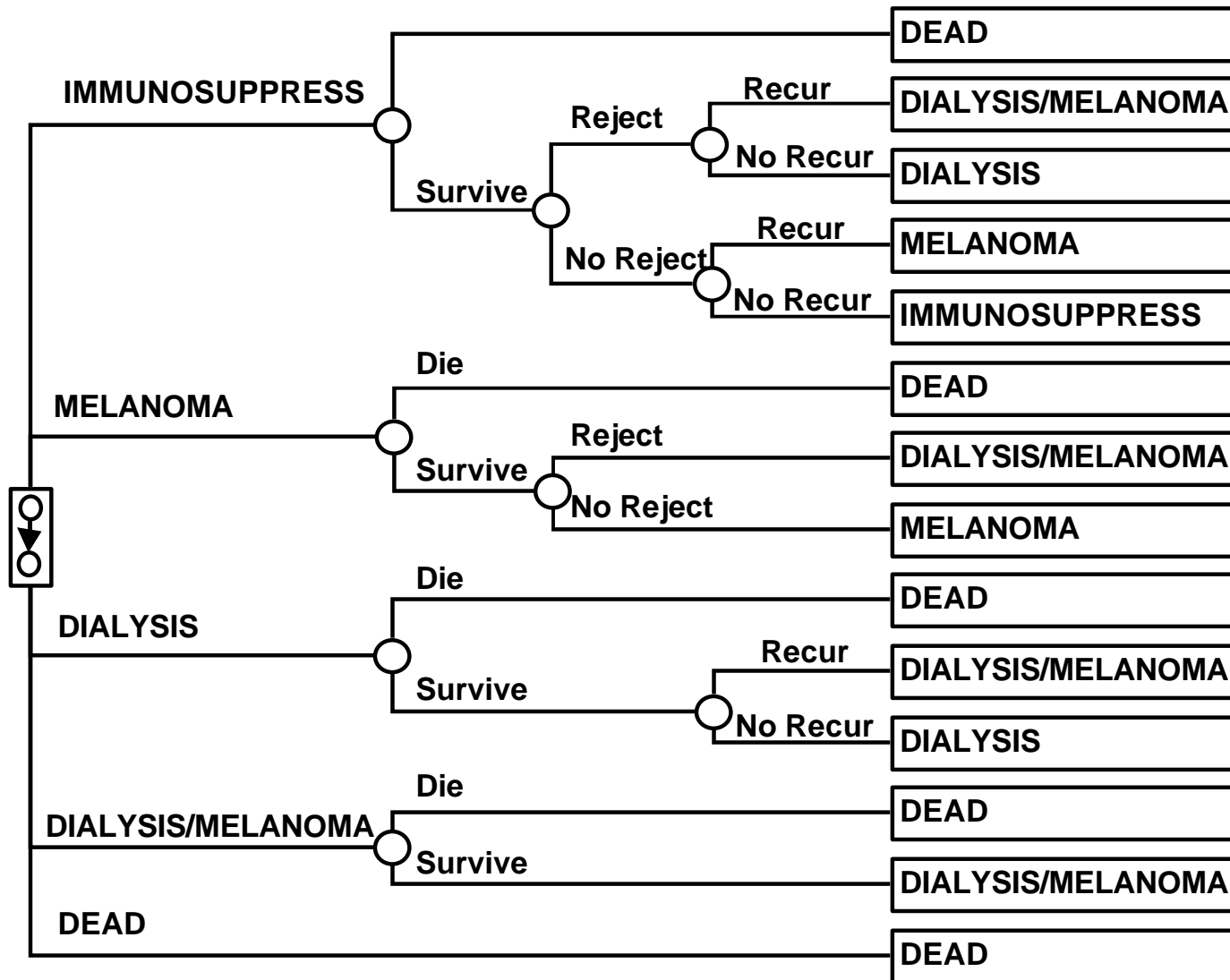


# ...What is a stochastic tree?

Using phantom nodes to avoid duplication

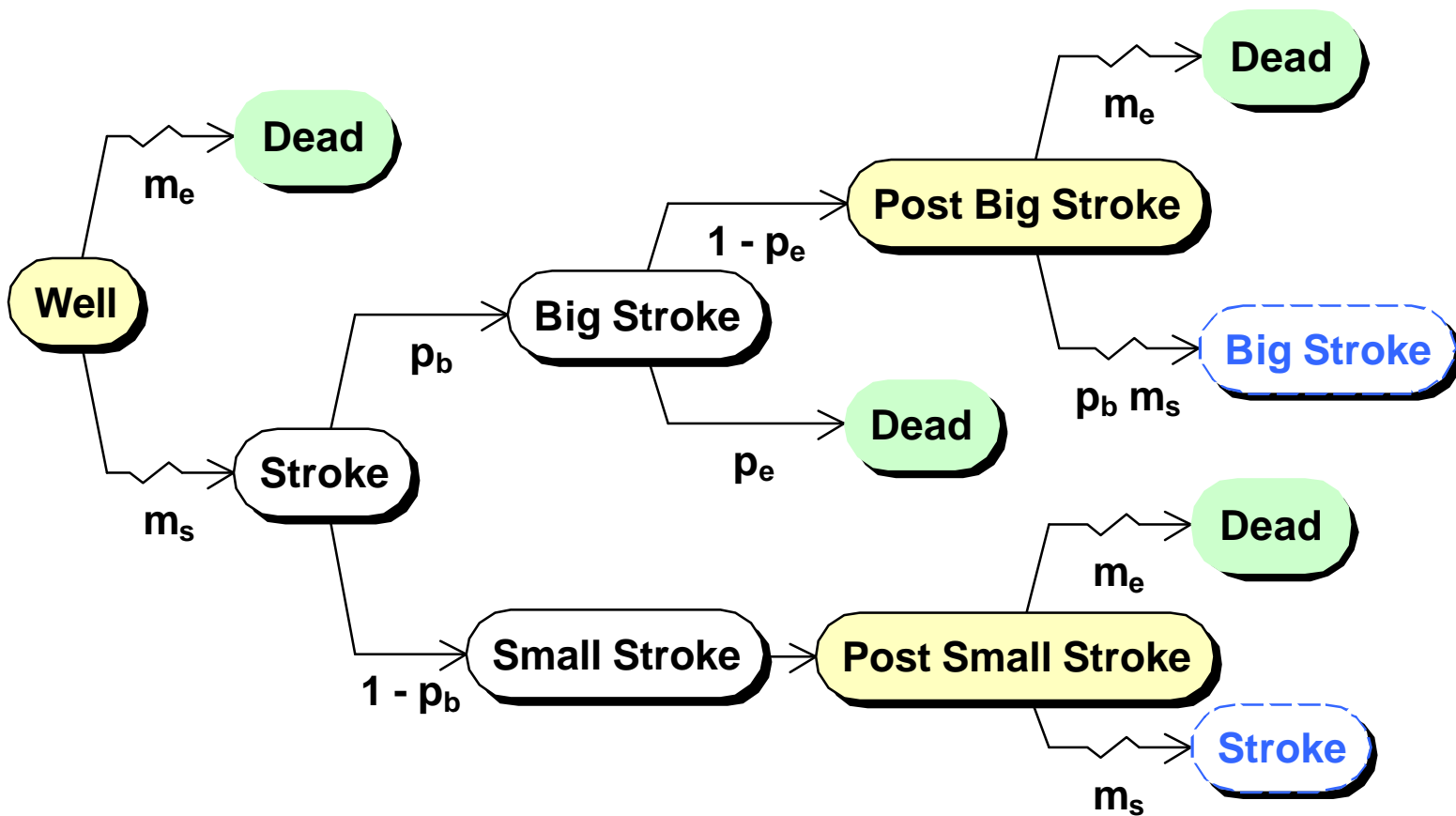


# Conventional method: Markov Cycle Tree



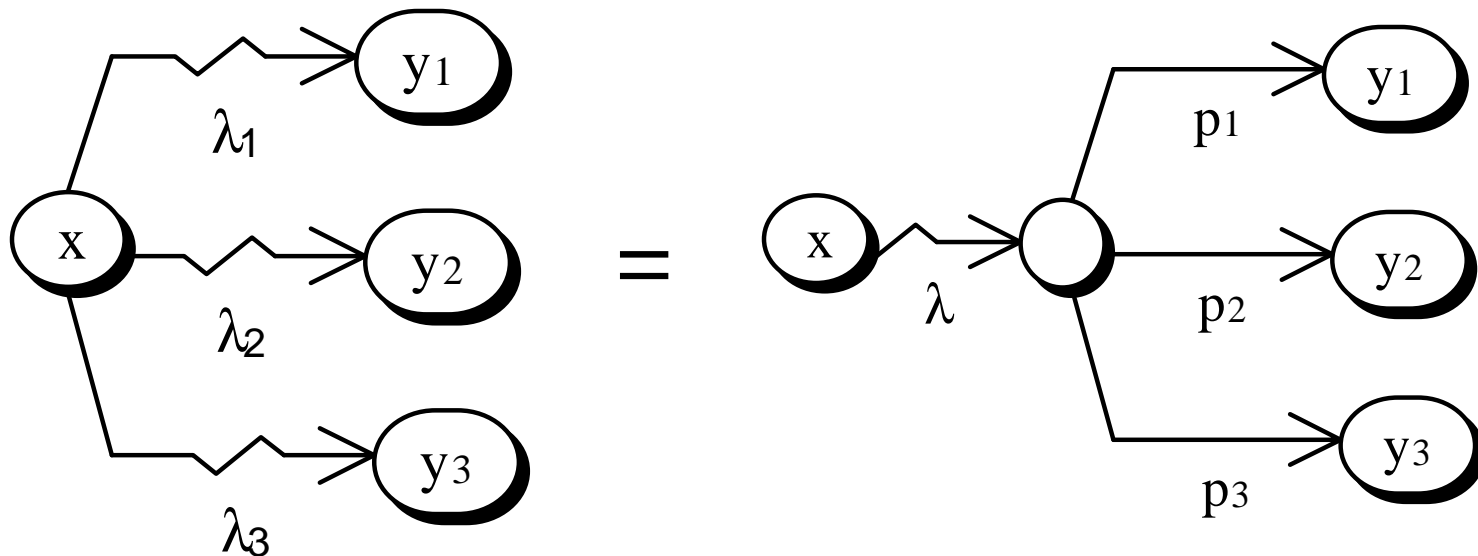
# Cycles in a stochastic tree

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



# Transforming stochastic trees

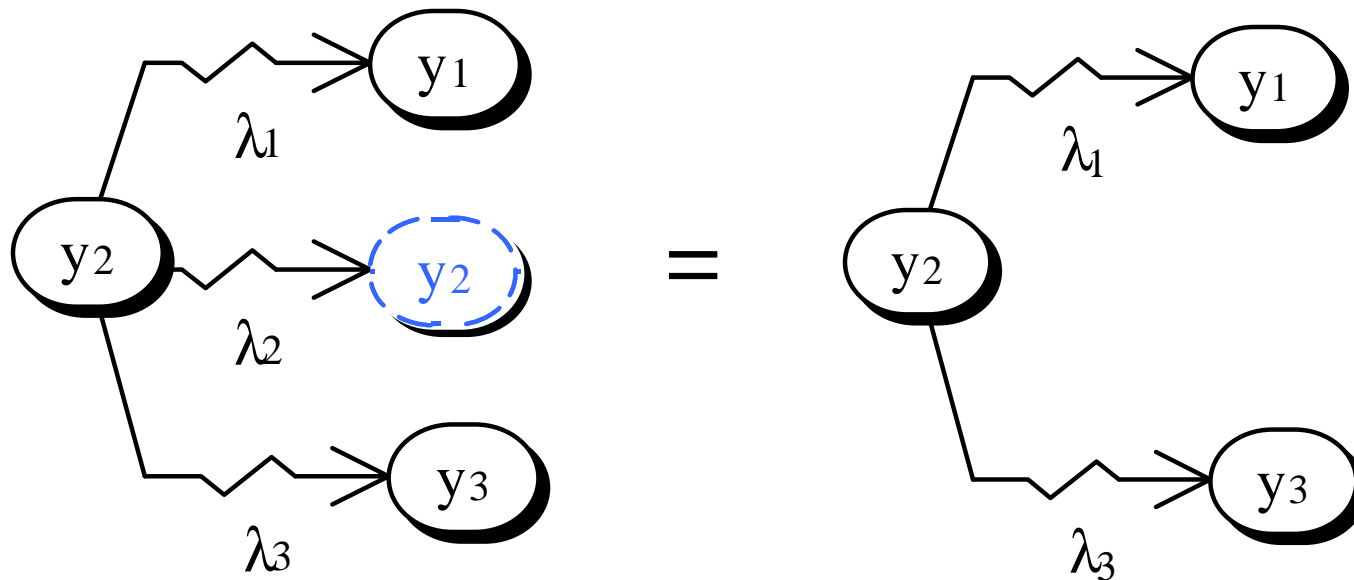
- Superposition / Decomposition



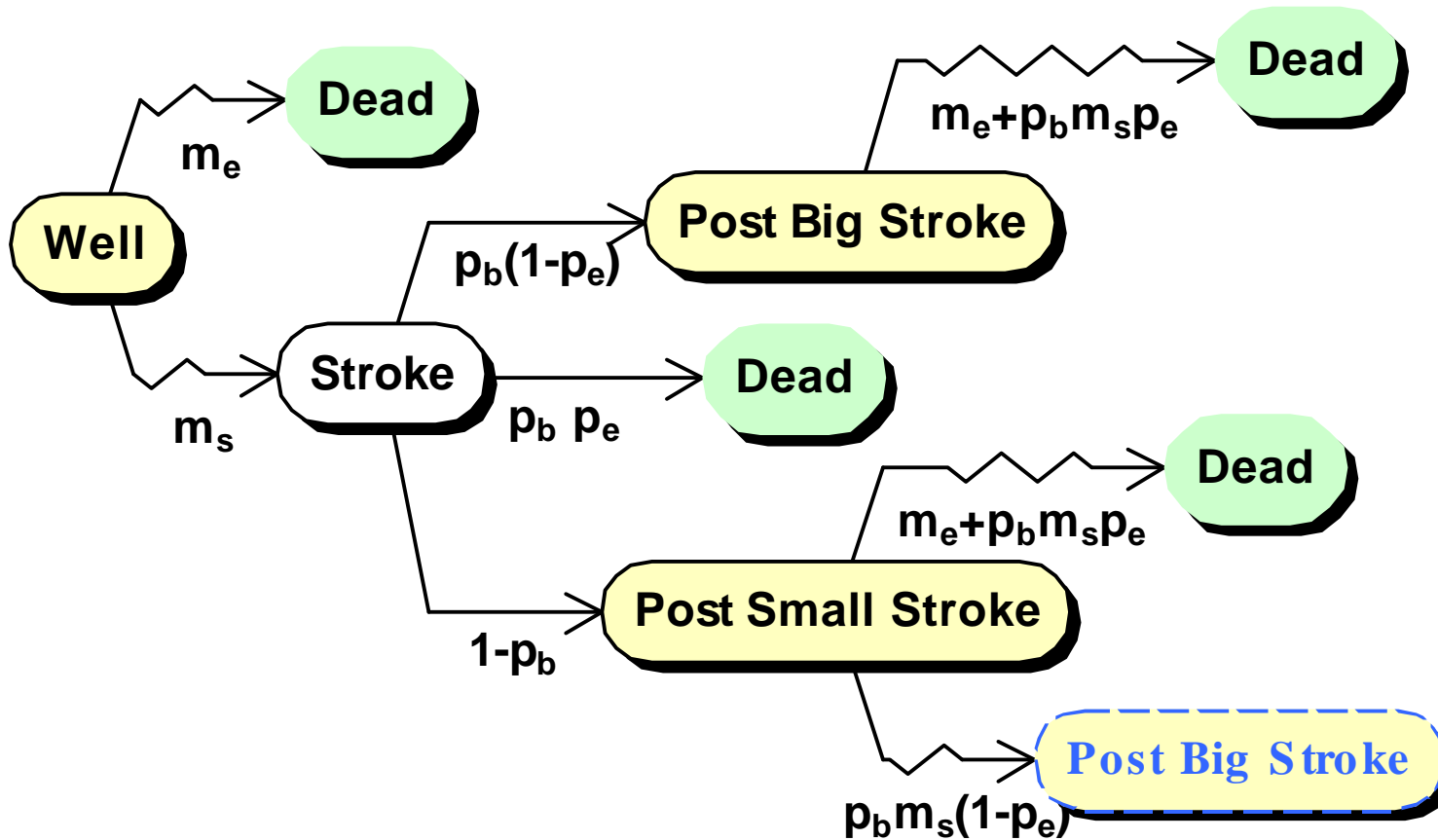
$$\lambda = \lambda_1 + \lambda_2 + \lambda_3 \quad p_i = \frac{\lambda_i}{\lambda}$$

## ...Transforming stochastic trees

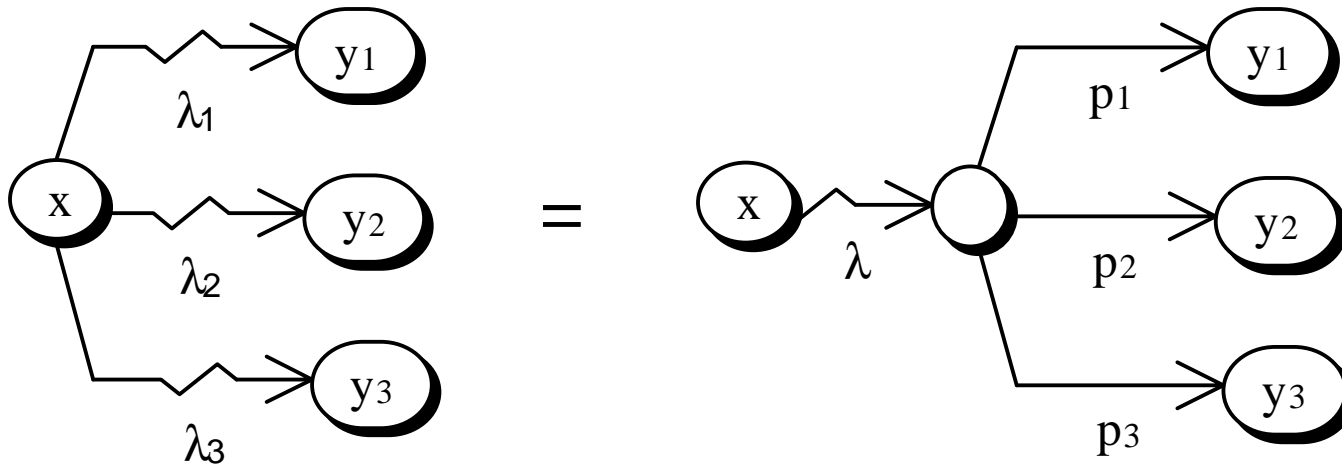
- Eliminating self-transitions



# ...Transforming stochastic trees



# Stochastic tree rollback



$L(x)$  = Mean QALY beginning at  $x$

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

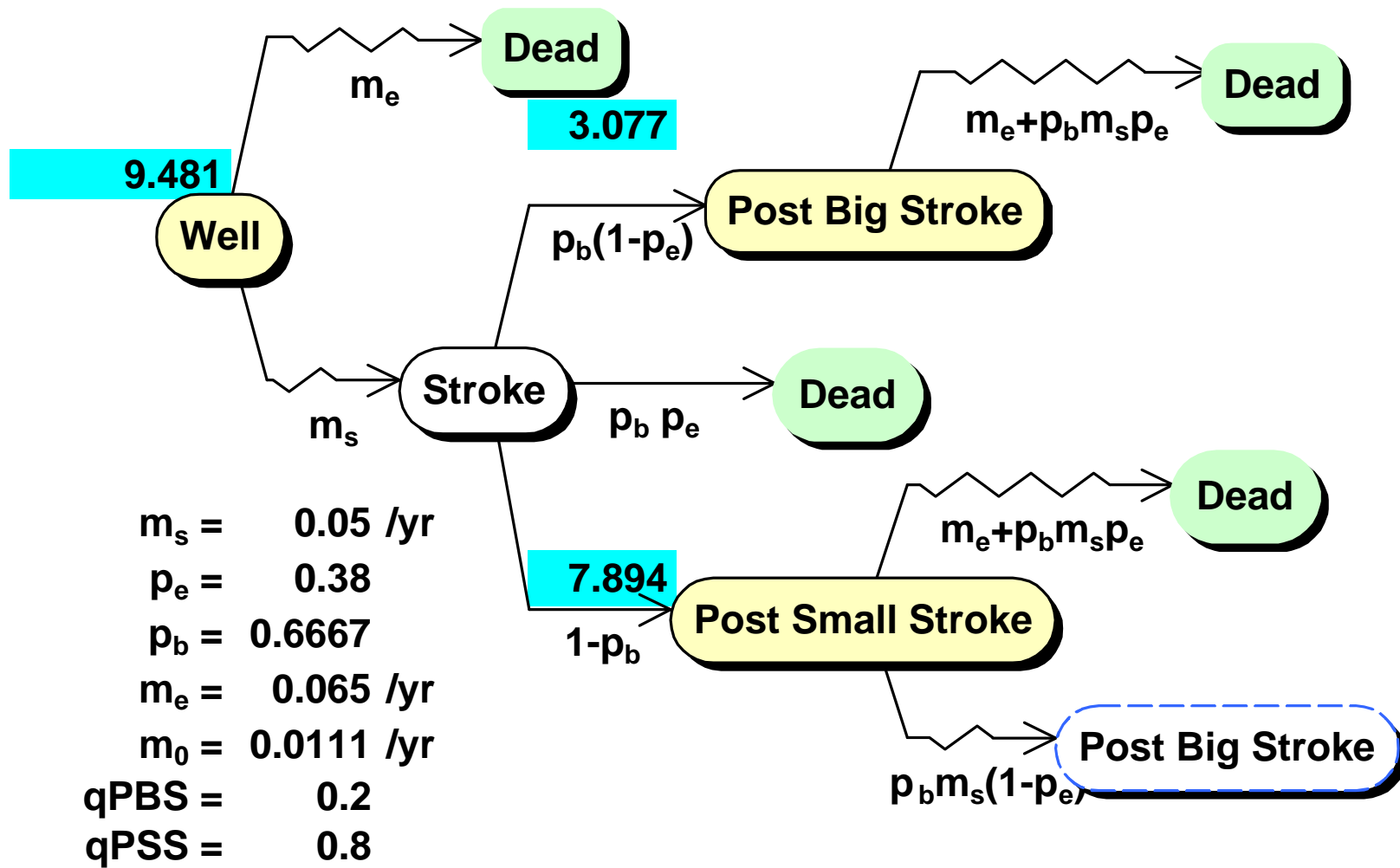
- Rollback without discounting

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

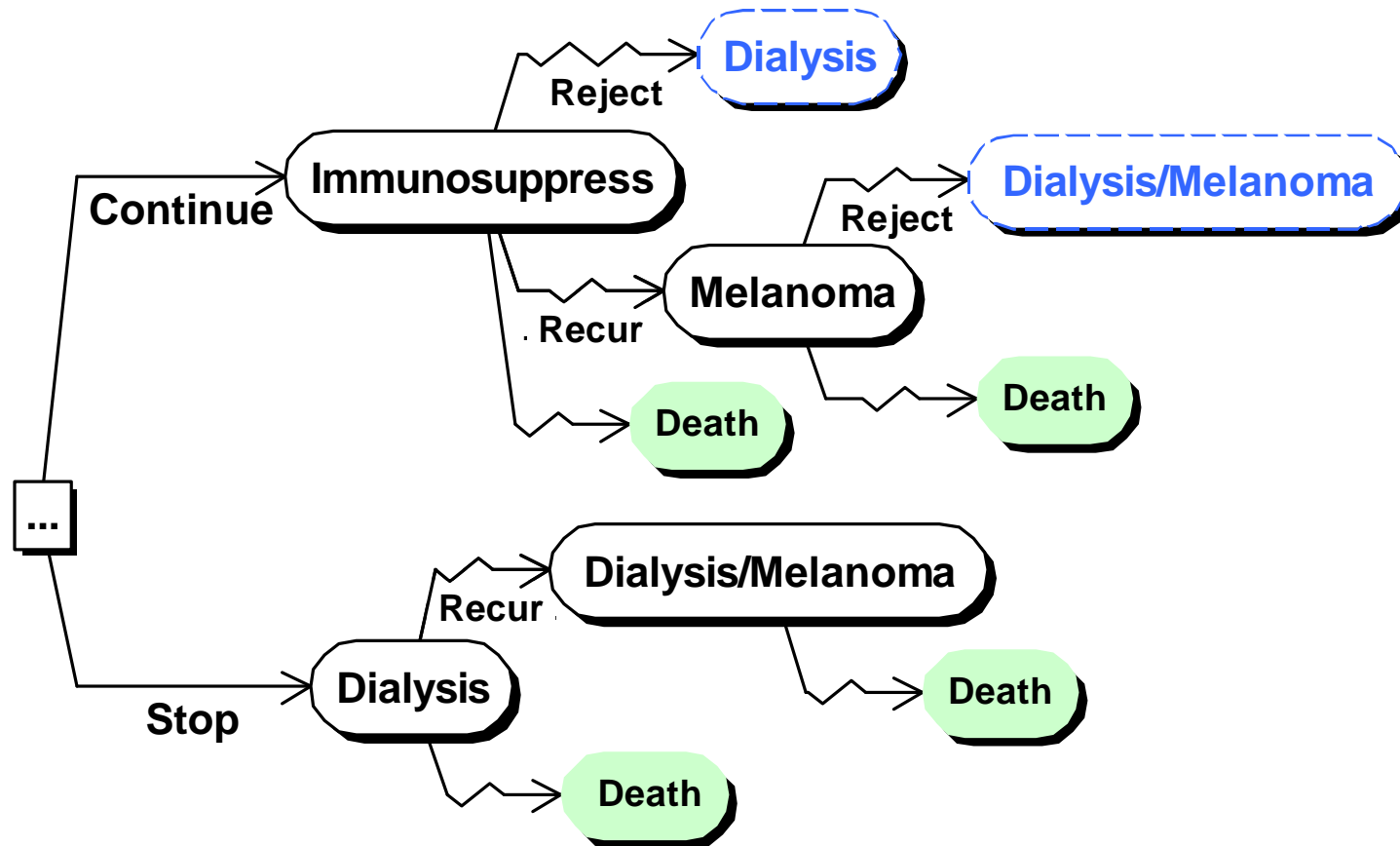
- Rollback with discount rate  $\alpha$

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

# Stochastic tree rollback

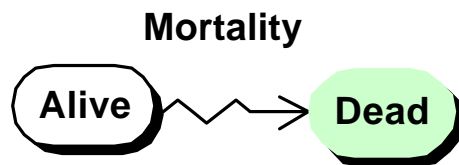
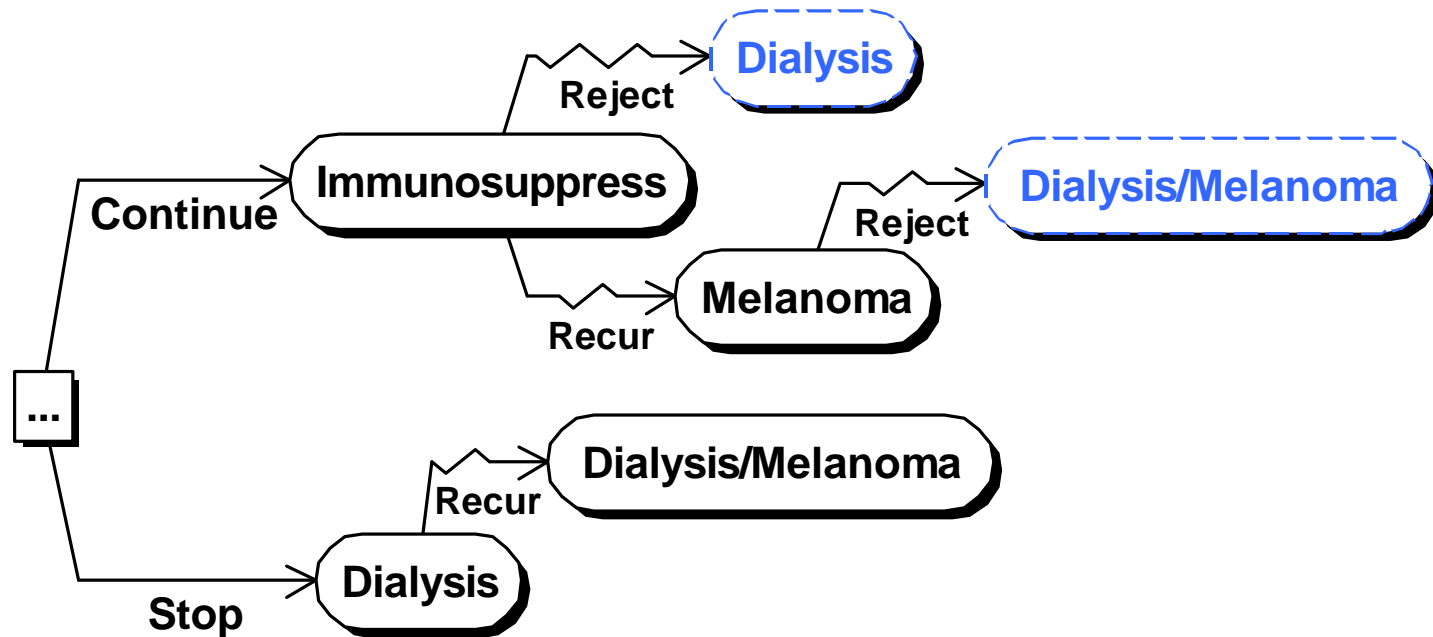


# Factoring stochastic trees

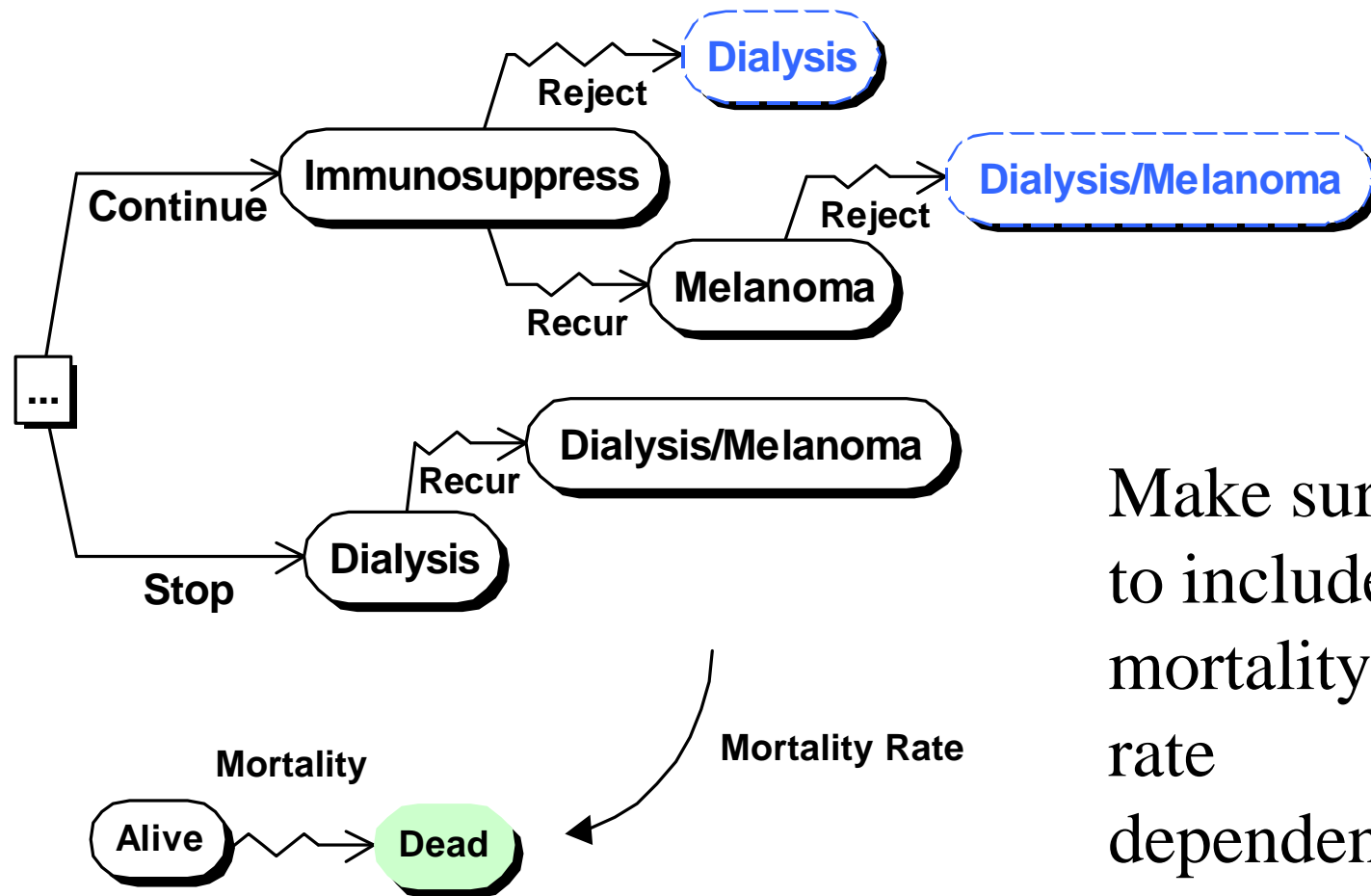


Death is a forgone conclusion, so separate it out ...

# Factoring stochastic trees



# Factoring stochastic trees

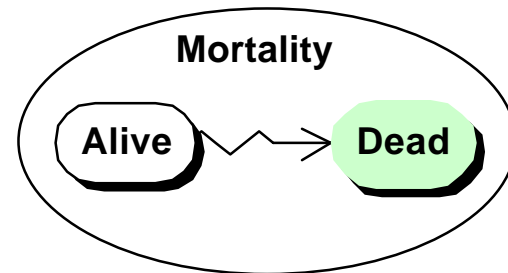
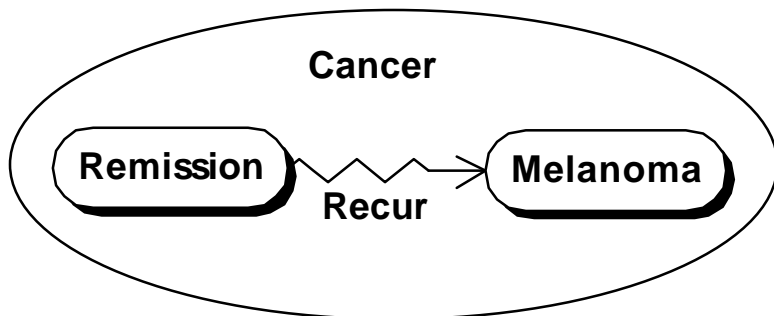
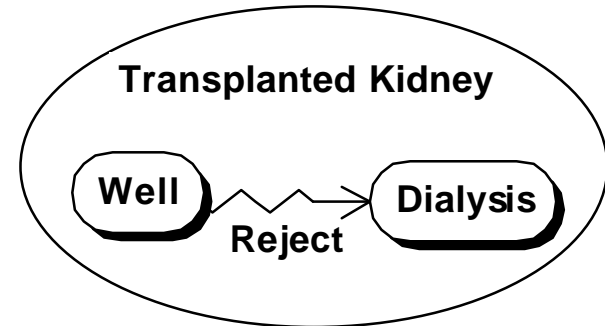
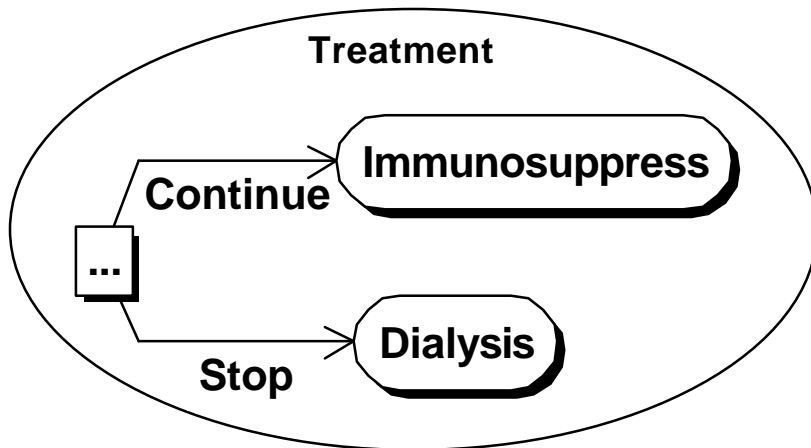


Make sure  
to include  
mortality  
rate  
dependency

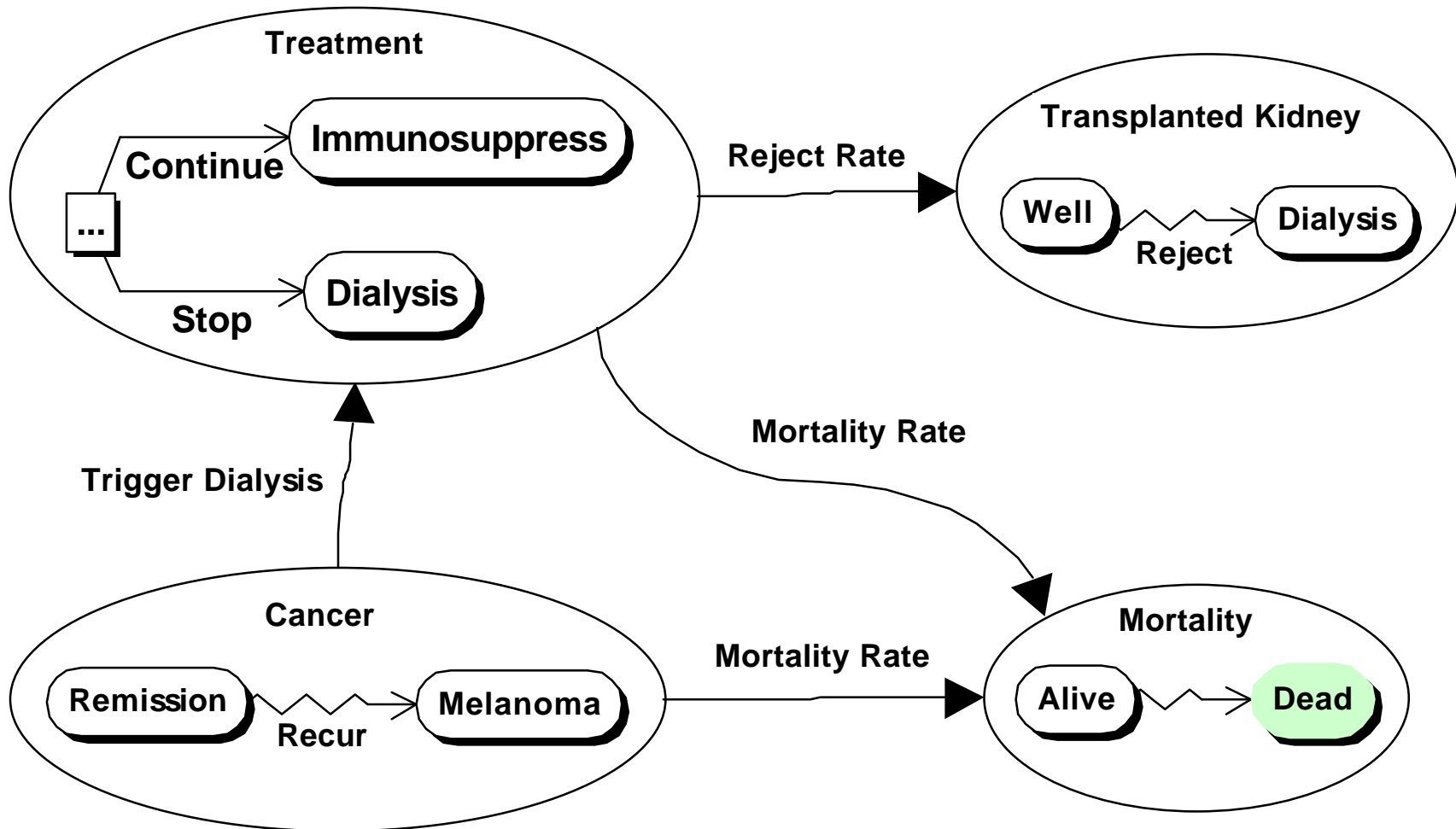
## Further factoring...

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

# ...Further factoring



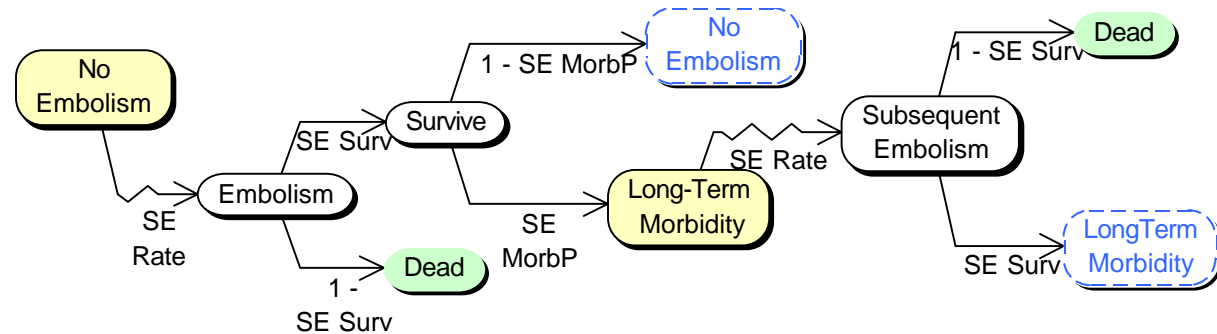
# ...Further factoring (with dependencies)



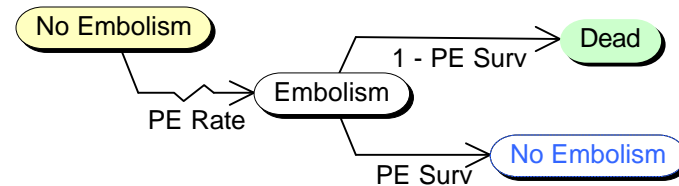
# ...Factoring stochastic trees

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

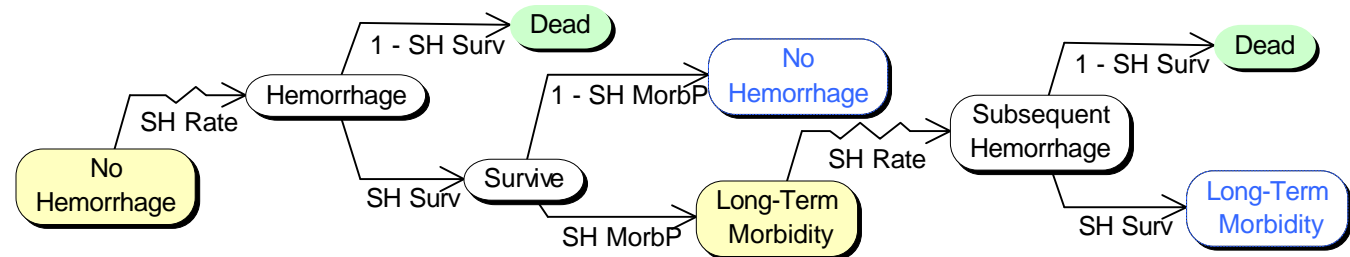
Systemic embolism



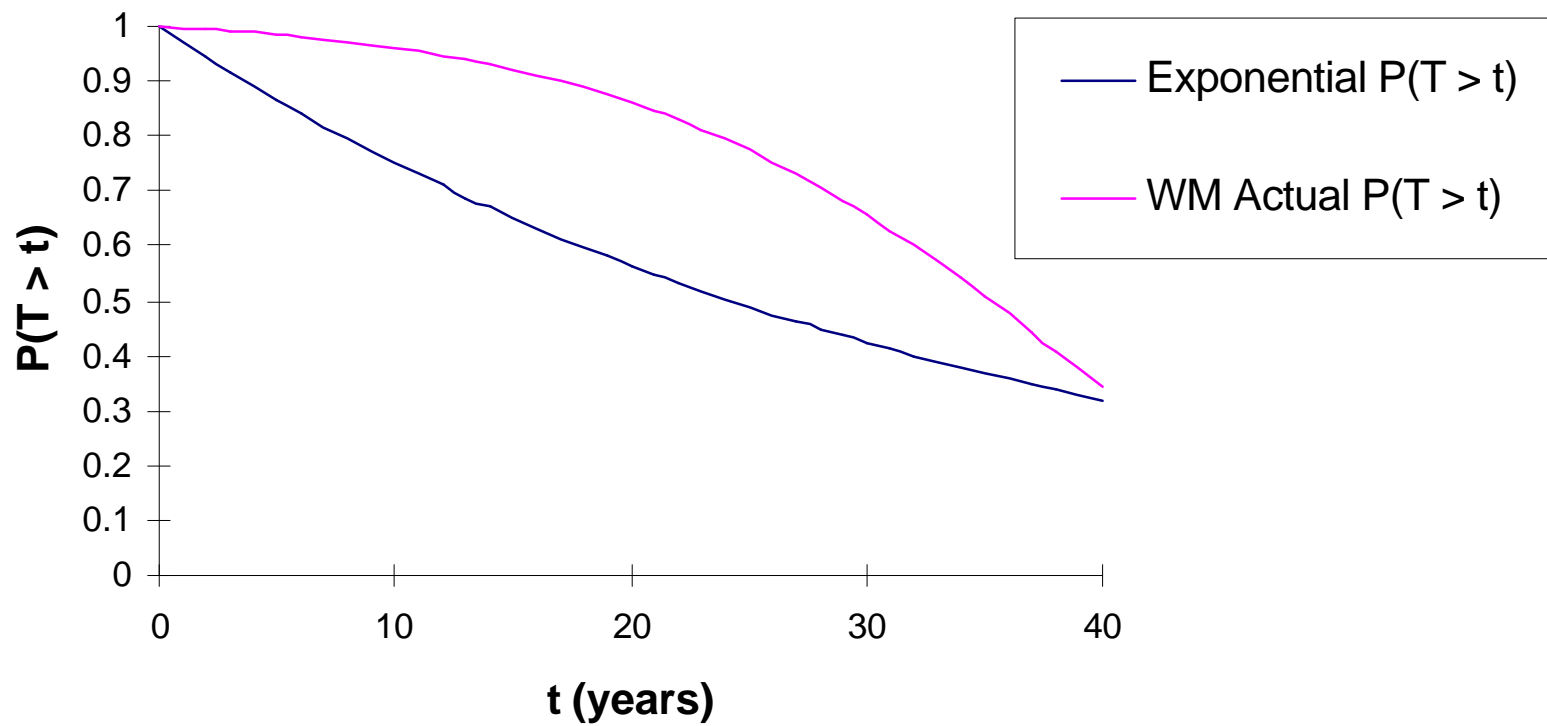
Pulmonary embolism



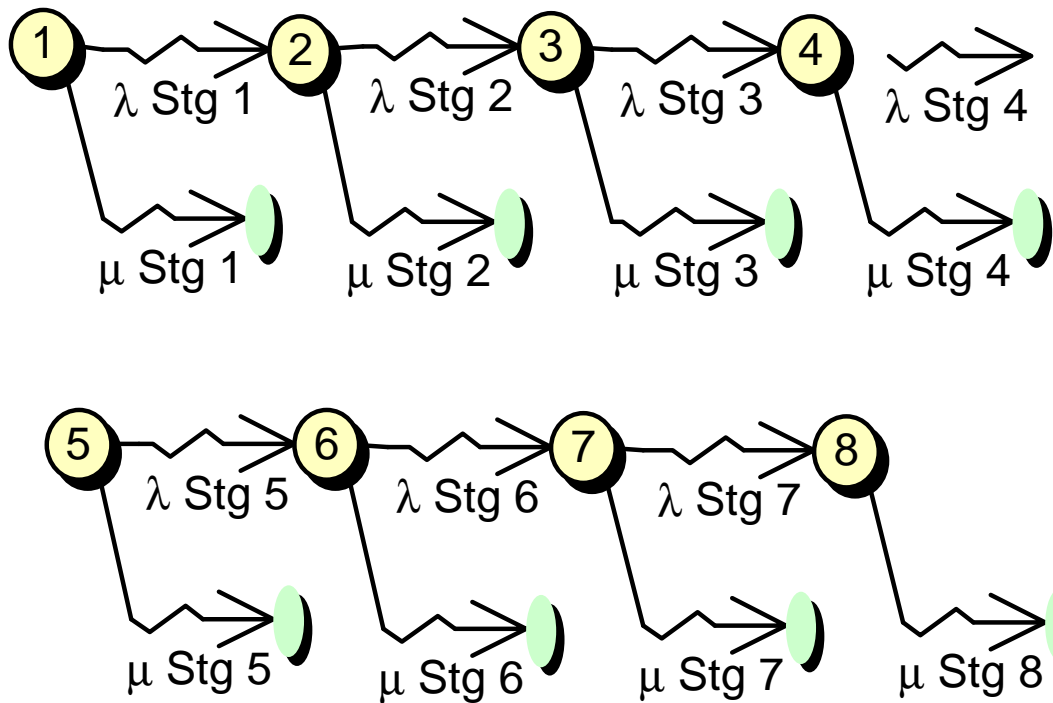
Systemic hemorrhage



# Approximating human survival



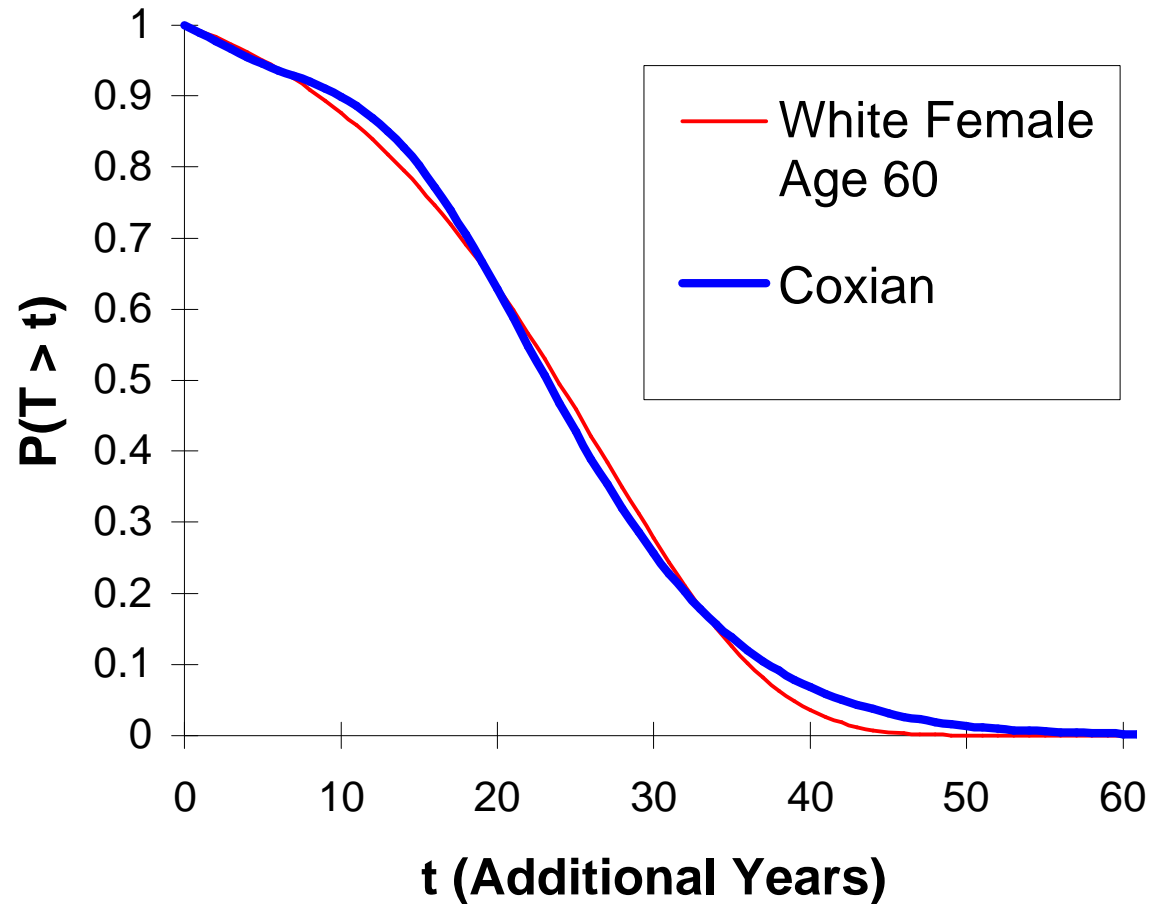
# Coxian approximation to human mortality



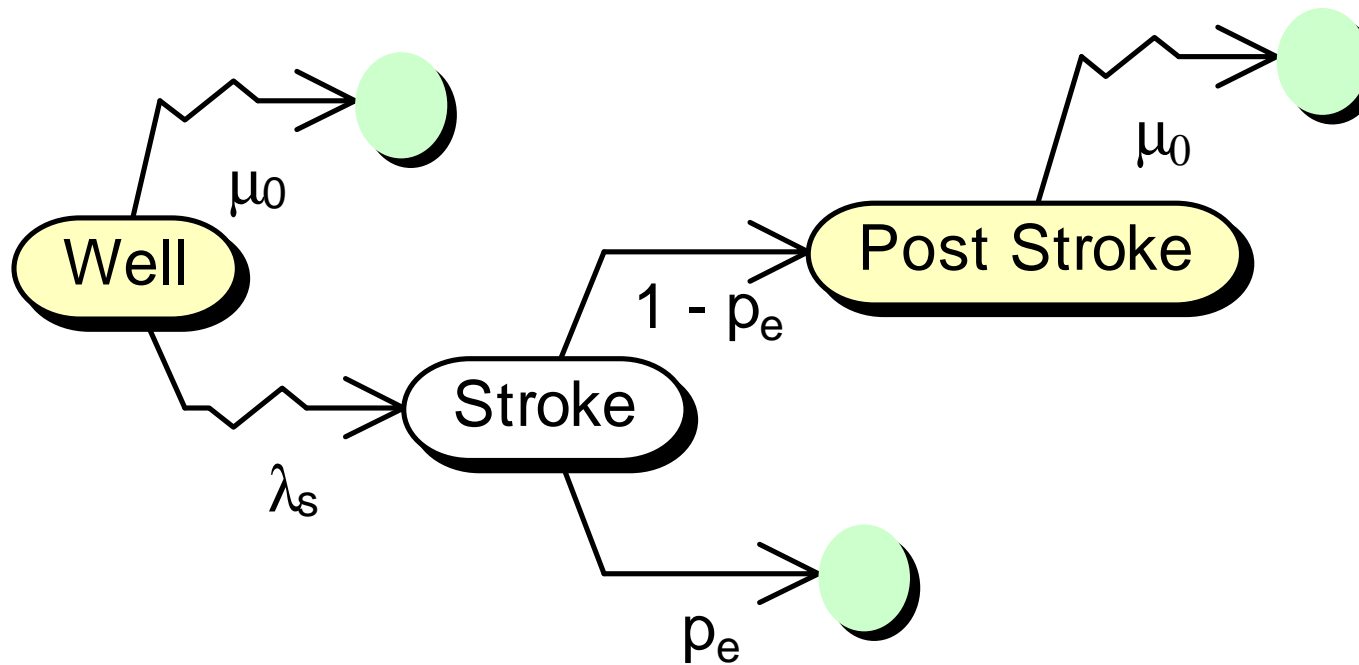
60-year-old white female

	$\lambda$	$\mu$
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

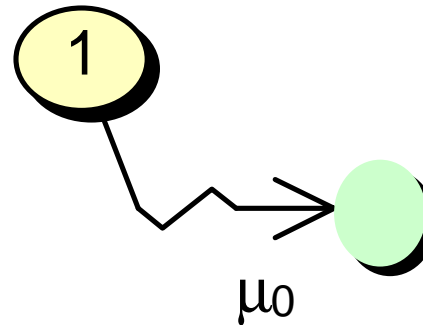


# Factoring out mortality

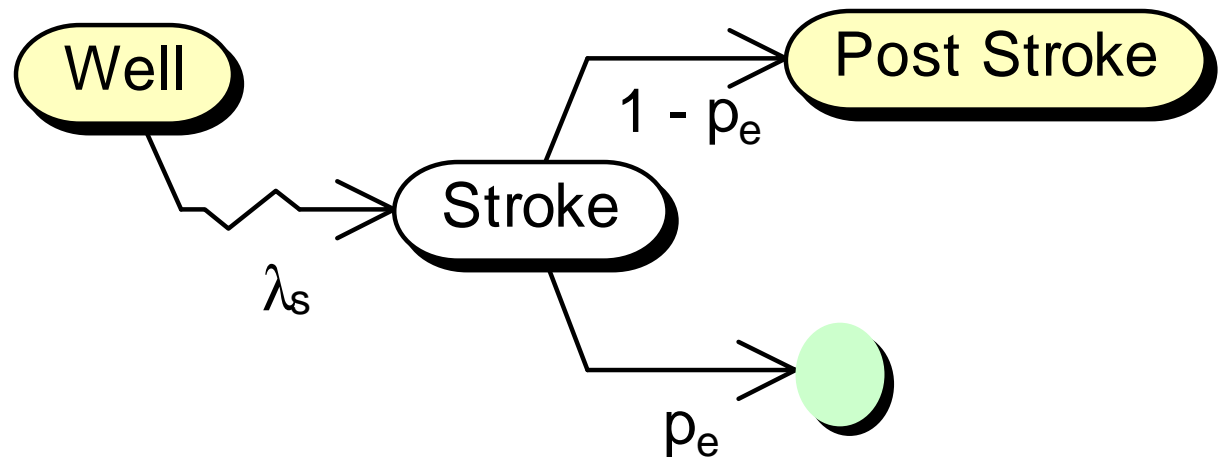


## ...Factoring out mortality

Background mortality

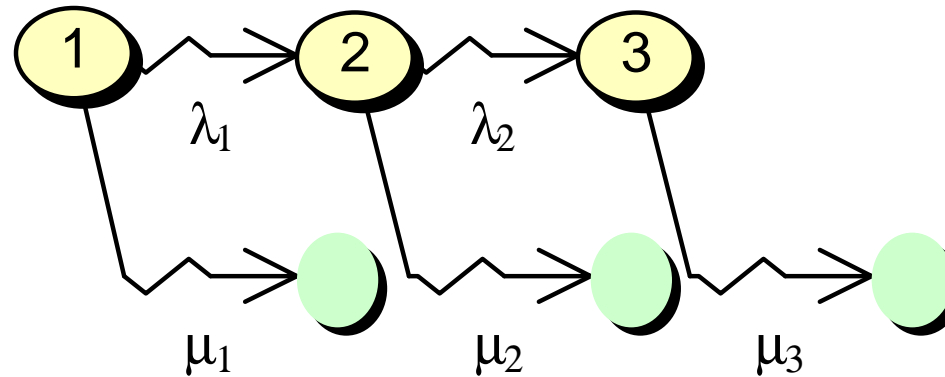


Stroke morbidity

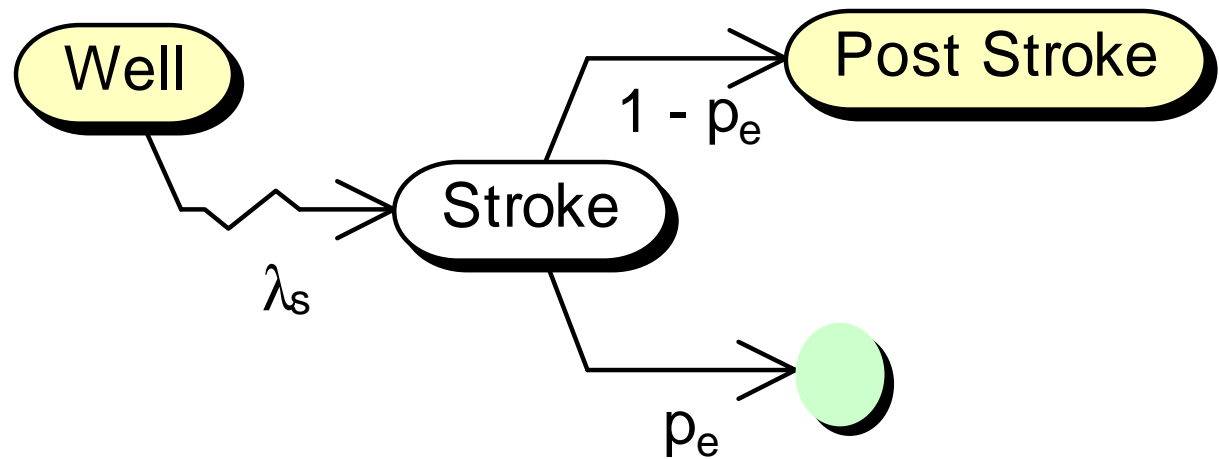


## ...Factoring out mortality

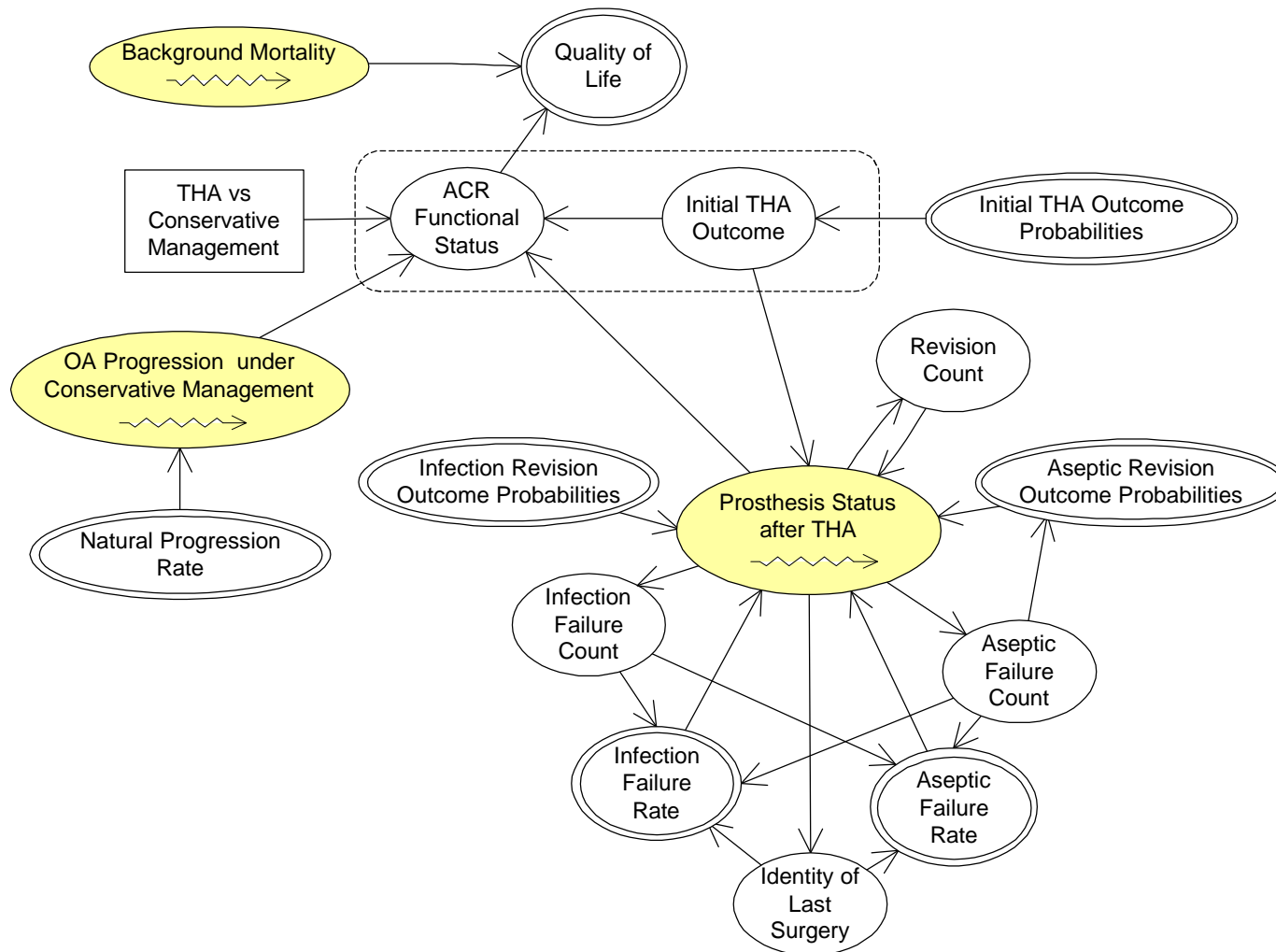
Background mortality



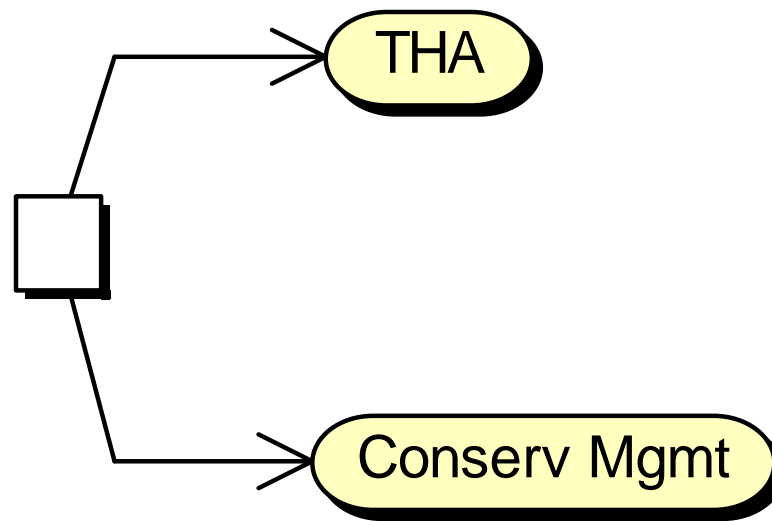
Stroke morbidity



# THA model (Chang, Pellissier & Hazen 1996)



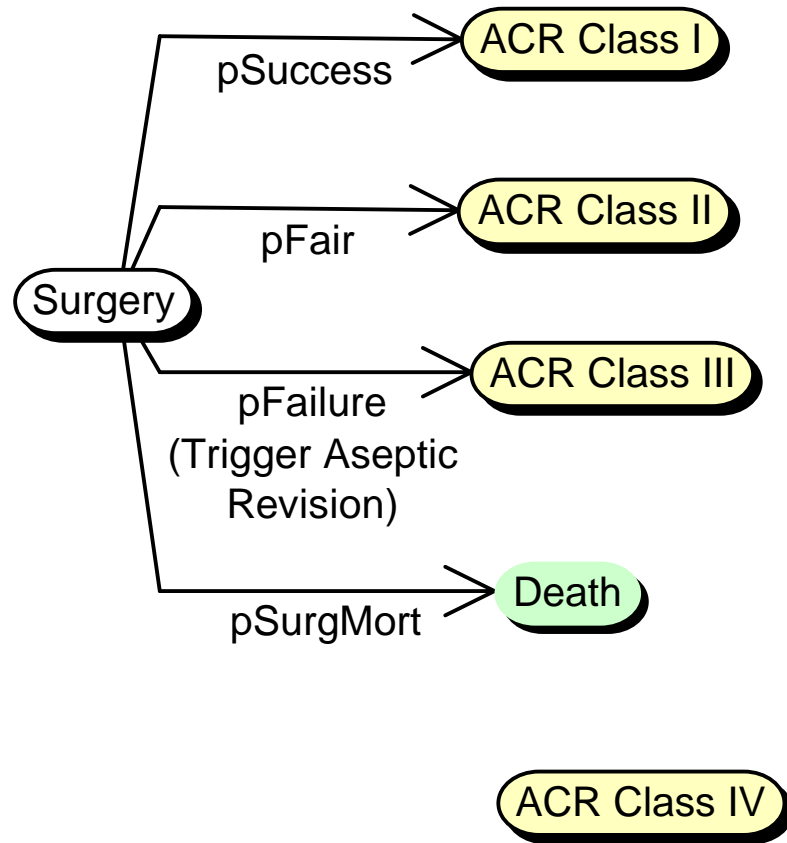
# THA vs. Conservative Management



# ACR functional status

Class	Description
I	Complete ability to carry on all usual duties without handicap
II	Adequate for normal activities despite handicap of discomfort or limited motion in the hip
III	Limited only to little or none of duties of usual occupation or self-care
IV	Incapacitated, largely or wholly bedridden or confined to wheelchair, little or no self-care

# ACR Functional Status / Initial THA Outcome

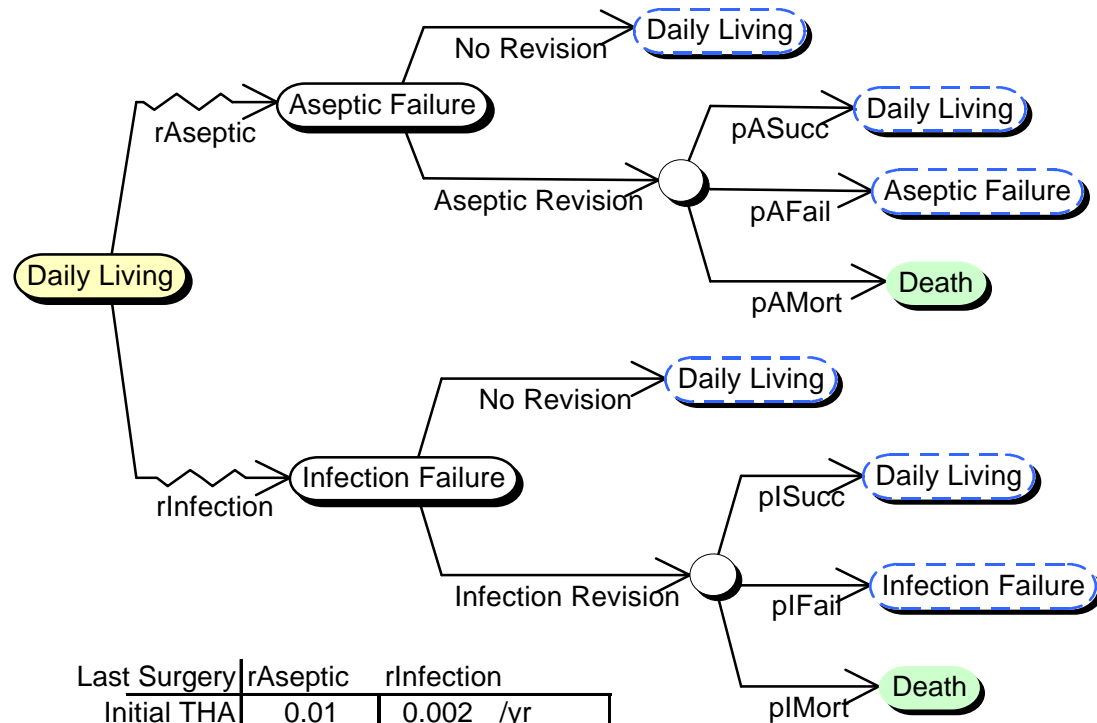


$p_{\text{Success}} = 0.6925$   
 $p_{\text{Fair}} = 0.243$   
 $p_{\text{Failure}} = 0.06$   
 $p_{\text{SurgMort}} = 0.0045$

$q_{\text{I}} = 1$   
 $q_{\text{II}} = 0.8$   
 $q_{\text{III}} = 0.5$   
 $q_{\text{IV}} = 0.3$

Discount Rate = 3%

# Prosthesis Status After THA



Last Surgery	rAseptic	rInfection
Initial THA	0.01	0.002 /yr
A or I Revision 1	0.04	0.02 /yr
A or I Revision 2	0.05	0.035 /yr
A or I Revision 3	0.1	0.05 /yr

Current Revision	pASucc	pAFail	pAMort
Rev 1	0.7015	0.2865	0.012
Rev 2	0.6363	0.3517	0.012
Rev 3	0.8477	0.1403	0.012

pISucc	pIFail	pIMort
0.7692	0.2115	0.0193

# Last Surgery

Initial THA

Aseptic Revision

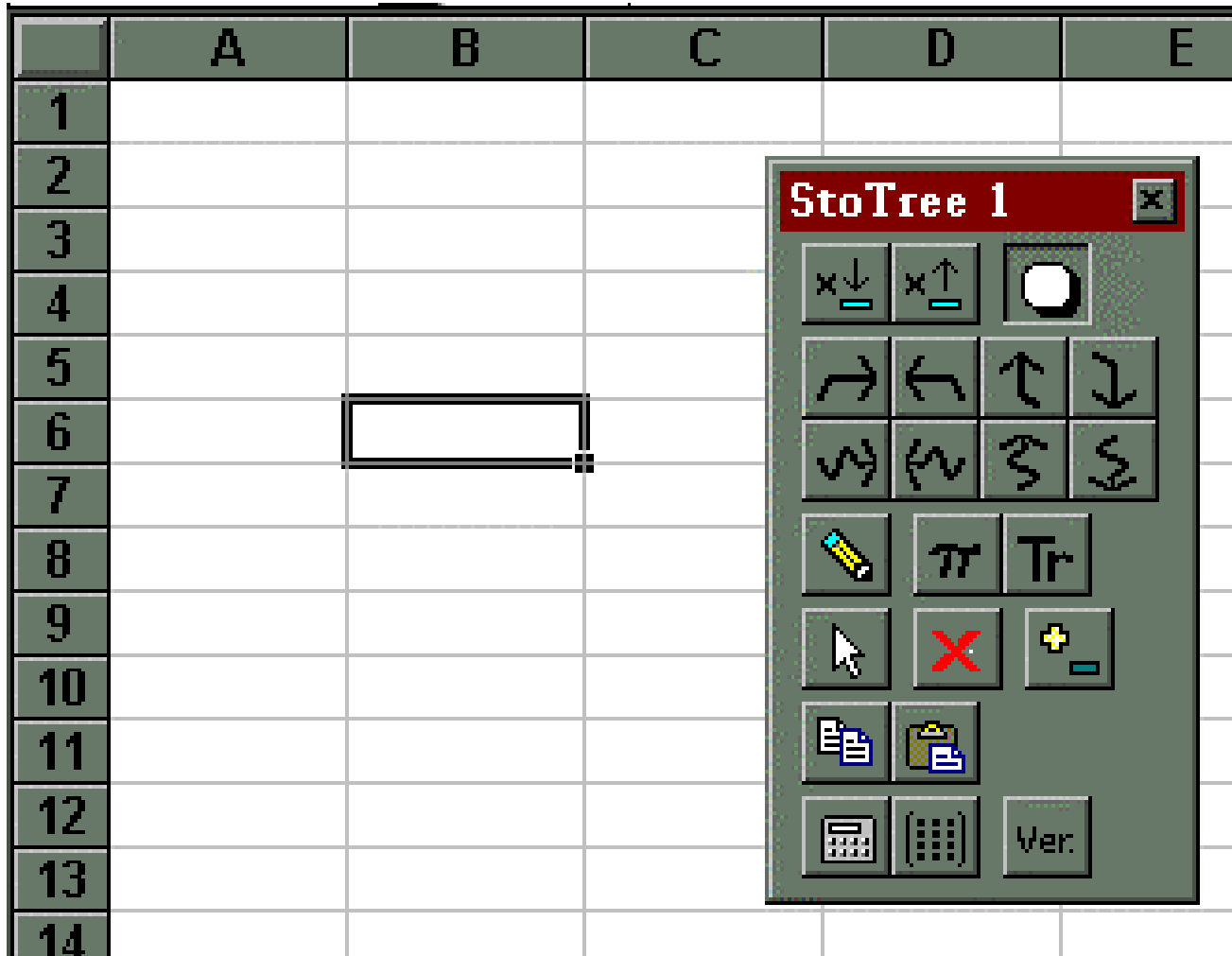
Infection Revision

# Conservative Management

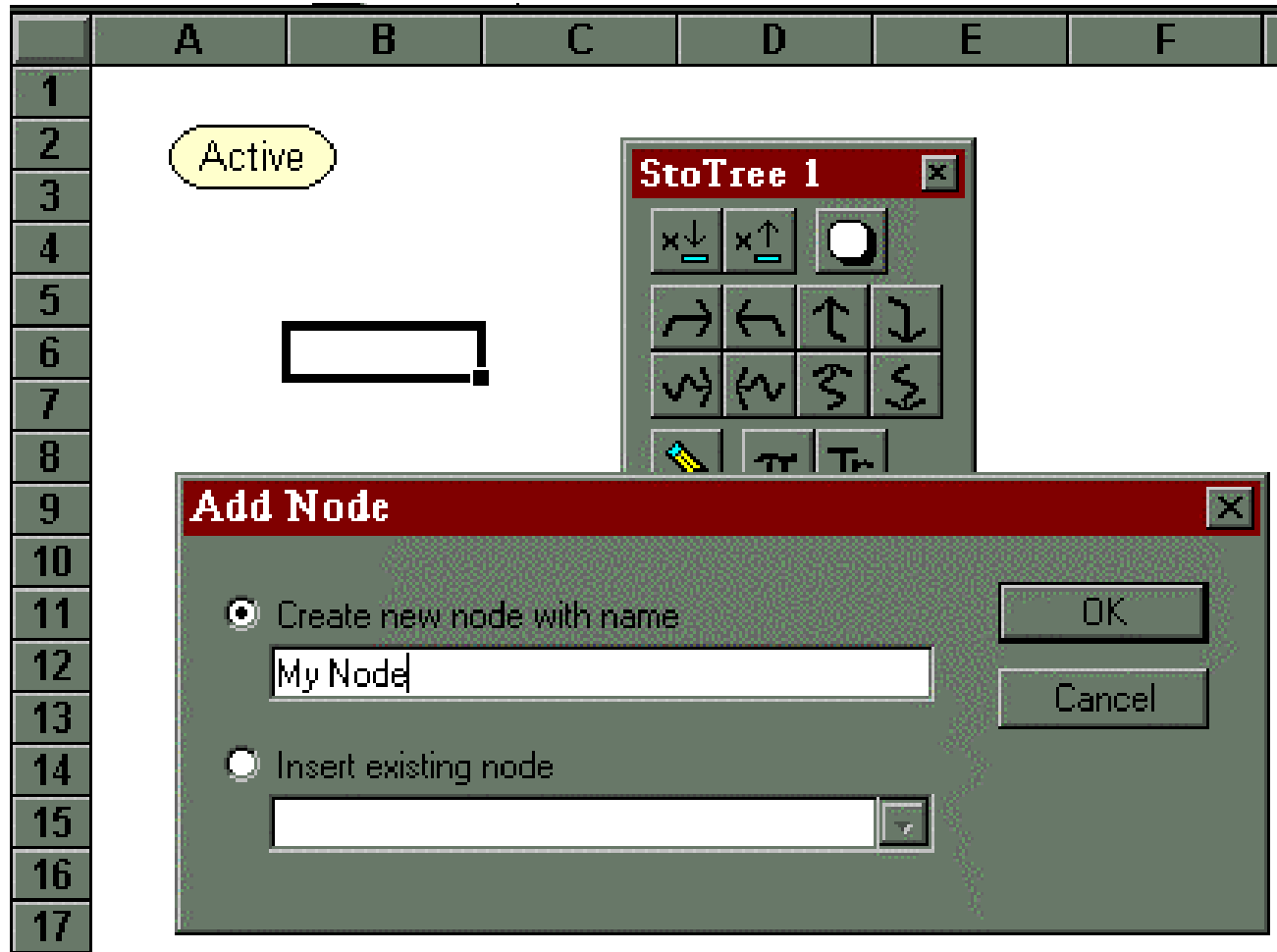


$$r_{\text{Natural}} = 3.297\% / \text{yr}$$

# The StoTree modeling environment

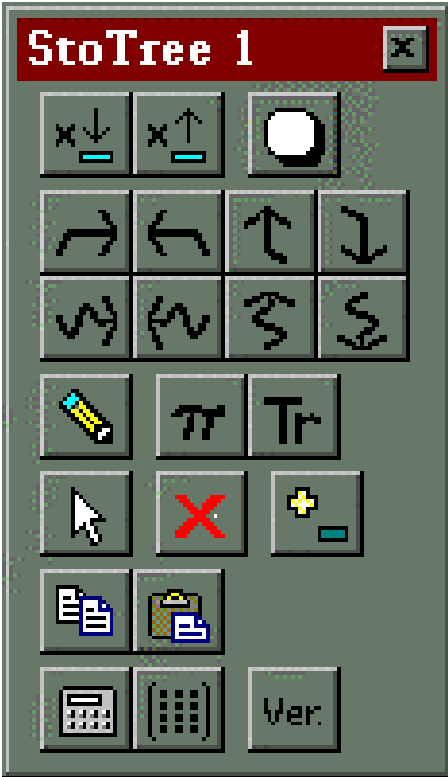


# The StoTree modeling environment



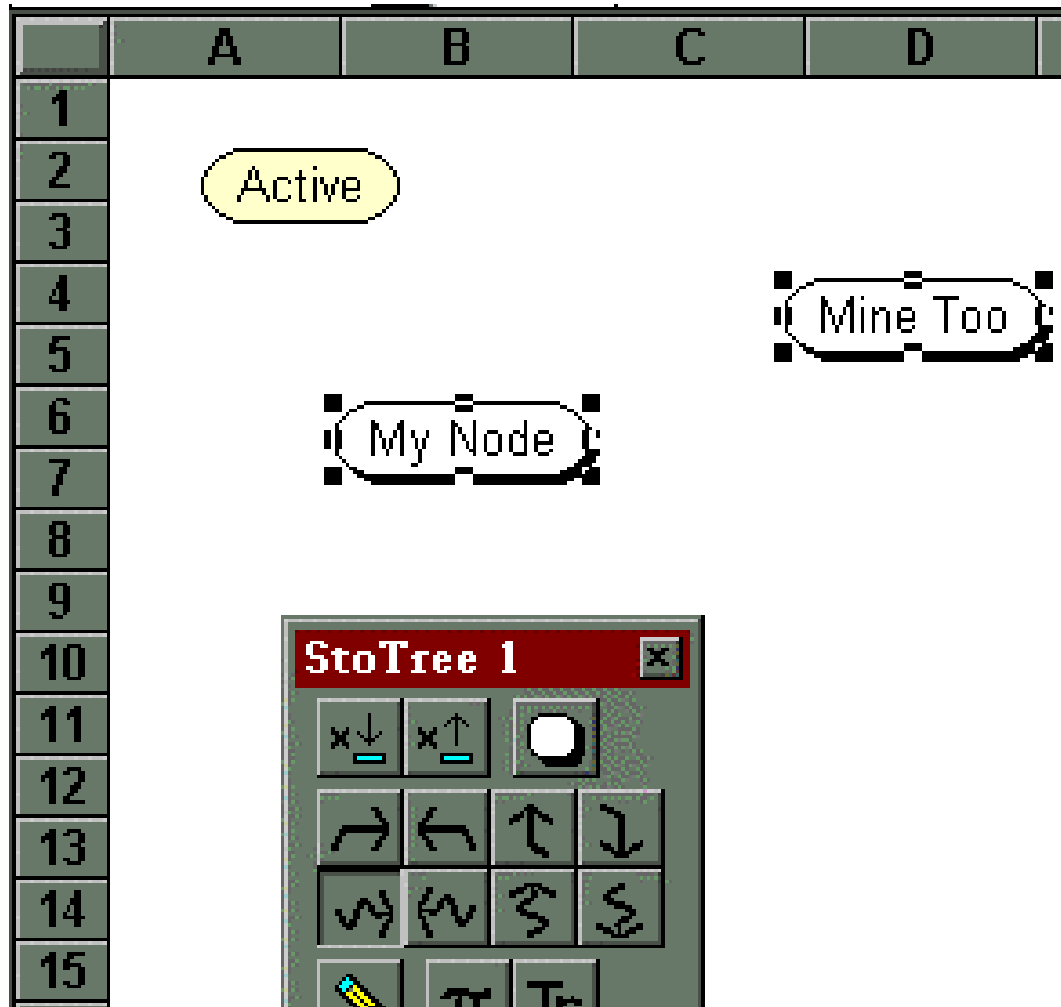
# ...StoTree modeling environment

	A	B	C	D	E
1					
2		Active			
3					
4					
5					
6			My Node		
7					
8					
9					
10					
11					
12					
13					
14					

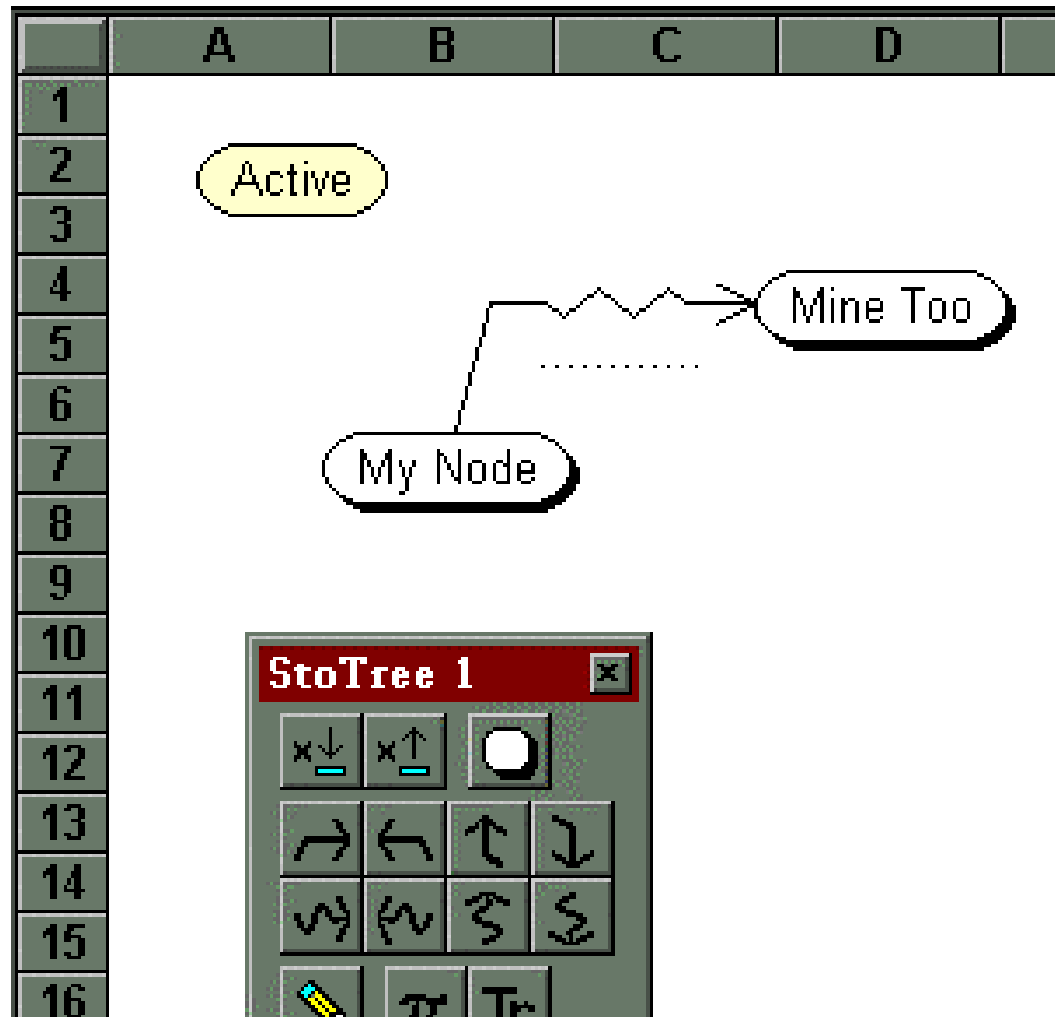


The image shows a software interface for a modeling environment. It features a grid with columns labeled A through E and rows numbered 1 through 14. In column B, row 2, there is a yellow oval containing the text "Active". In column C, row 6, there is a white oval with a black border containing the text "My Node". To the right of the grid is a vertical toolbar titled "StoTree 1" with a close button (X) in the top right corner. The toolbar contains several icons: a downward arrow with an 'x' and a blue underline, an upward arrow with an 'x' and a blue underline, a white circle, four arrows pointing right, left, up, and down, four wavy arrows pointing right, left, up, and down, a yellow pencil, a pi symbol ( $\pi$ ), a Tr symbol, a mouse cursor, a red X, a plus sign with a blue underline, a document icon, a clipboard icon, a calculator icon, a grid icon, and a button labeled "Ver."

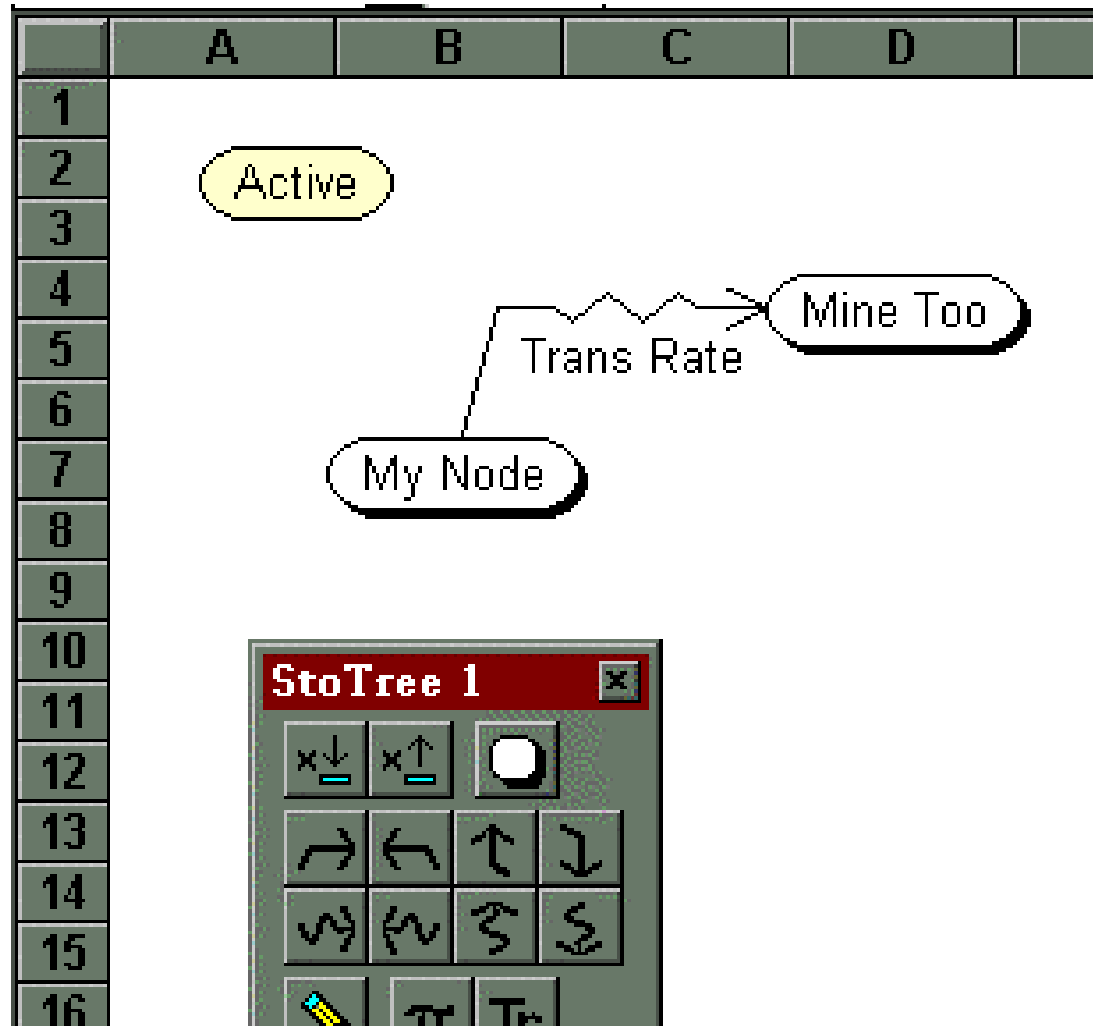
# ...StoTree modeling environment



# ...StoTree modeling environment

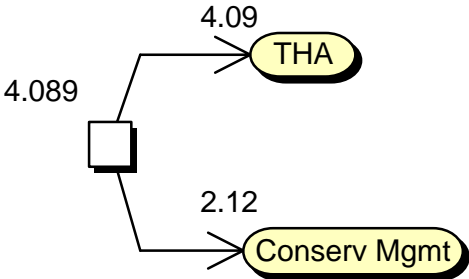


# ...StoTree modeling environment

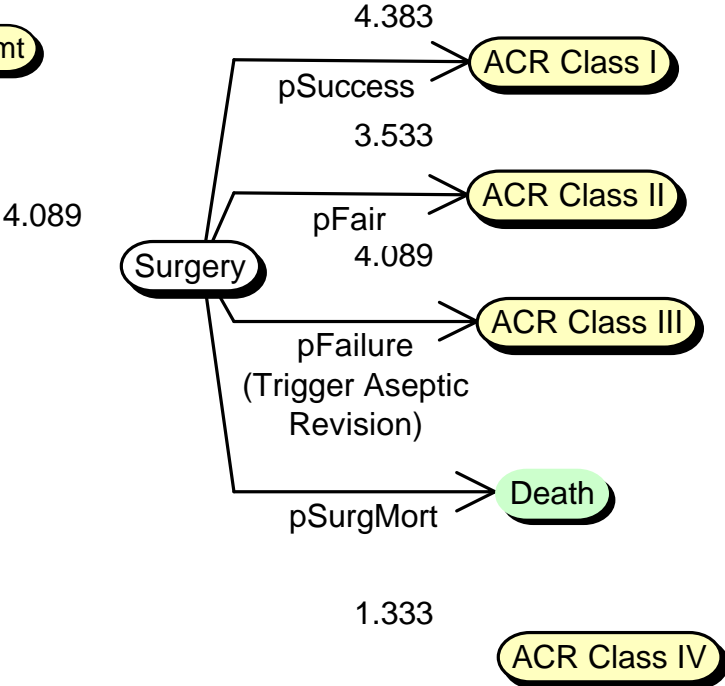


# Rollback in the THA model

85-year-old white male



3/11/99 4:54 Rollback  
 279 parameters examined  
 48 product nodes examined



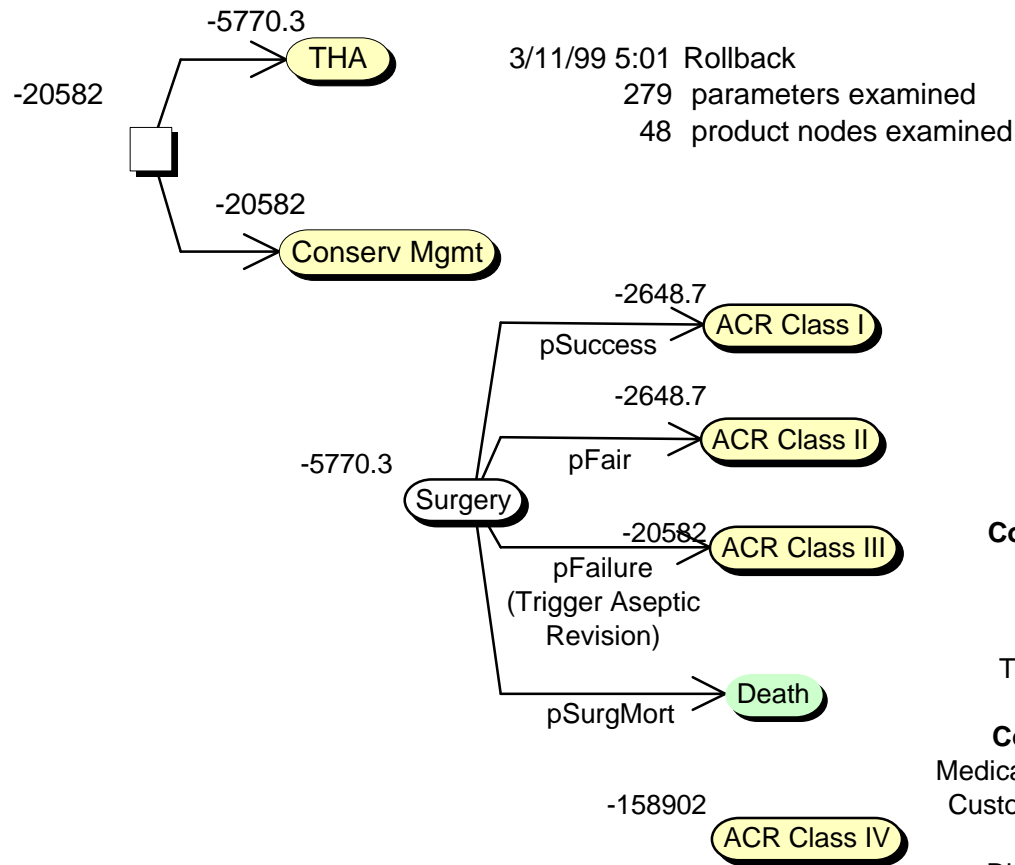
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 pFair = 0.243  
 pFailure = 0.06  
 pSurgMort = 0.0045

qI = 1  
 qII = 0.8  
 qIII = 0.5  
 qIV = 0.3

Discount Rate = 3%

# Cost-effectiveness for THA

85-year-old white male



pSuccess = 0.6925  
pFair = 0.243  
pFailure = 0.06  
pSurgMort = 0.0045

Costs per case	Primary		
	No THA	THA	Revision
Hospital	\$ -	\$ 17,000	\$ 20,000
Physician	\$ -	\$ 5,000	\$ 5,000
Rehabilitation	\$ -	\$ 3,000	\$ 3,000
Total Per Case	\$ -	\$ 25,000	\$ 28,000

Costs per year		
Medical Per Yr III IV	\$ 775	\$ 775
Custodial Per Yr IV	\$ 35,000	\$ 35,000

Discount Rate = 3%

# THA Cost-Effectiveness Results

	White Male Age 85		White Female Age 60	
	THA	Conserv	THA	Conserv
Mean Dctd Years in				
ACR Class I	2.944	0	9.717	0
ACR Class II	1.384	0	5.078	0
ACR Class III	0.063	3.952	0.608	11.39
ACR Class IV	0.022	0.49	0.48	4.634
Mean Dctd Life Expectancy	4.413	4.442	15.883	16.024
Mean Dctd QALY	4.089	2.123	14.23	7.087
Mean Dctd Costs				
Primary Surgery, Rehab	\$25,000	-	\$25,000	-
Revision Surgery, Rehab	\$4,929	-	\$12,284	-
Ongoing Medical	\$66	\$3,442	\$843	\$12,421
Custodial	\$776	\$17,140	\$16,789	\$162,175
Total	\$30,771	\$20,582	\$54,916	\$174,596
Marginal cost	\$10,189		\$(119,680)	
Marginal effectiveness (QALY)	1.966		7.143	
Marginal CE ratio	\$5,183		-	

## Ongoing Projects

- Total knee replacement (with Rowland Chang, Debbie Dobrez, Tina Chang)
- DCIS - Ductal carcinoma in situ (with Monica Morrow)
- Ovarian cancer screening (with Debbie Dobrez, David Cella)

# Questions?

