Decision Analysis & Cost-Effectiveness Analysis

Day 1

Stanford | Freeman Spogli Institute for International Studies

Stanford | Health Policy

Decision analysis

Overview

- Decision Analysis
  - Motivating examples
  - Introduction to decision science
  - Key elements of a decision analysis
  - Probability review, conditional probability, expected value
  - Construct a decision tree
  - Calculate expected value of alternatives
  - One-way sensitivity analysis
  - Threshold analyses (no treat, test, treat)
  - Expected value of perfect information

HPV vaccination

- Should children be vaccinated against the human papilloma virus (HPV)?
  - Should *my* child?
  - Should it be mandatory?

HPV vaccination

- Should children be vaccinated against the human papilloma virus (HPV)?

"Ninety-five percent of women who are infected with HPV never, ever get cervical cancer. It seemed very odd to be mandating something for which 95 percent of infections never amount to anything."

"If in 20 years time, my daughter…develops cervical cancer, and I didn't give her the vaccine, I'm going to be looking pretty hard in the mirror at myself."

"My daughter is so not sexually active that it seems very premature to even think about protecting her from cervical cancer."

"HPV Vaccine: The Science Behind The Controversy", Richard Knox, NPR News, Sept. 19, 2011
http://www.npr.org/2011/09/19/140543977/hpv-vaccine-the-science-behind-the-controversy

PSA screening

- Should men over 50 be routinely offered prostate specific antigen (PSA) testing?

“Prostate cancer remains the second-leading cause of cancer deaths in American men, but fatalities have dropped by up to 40 percent since the PSA screenings came on the scene nearly two decades ago.”

"Many people assume that if we screen for prostate cancer, that it will give them a lower chance of getting the disease and dying of it. And the outcomes of screening...tend to be relatively modest, but they come with a whole lot of terrible side effects."

“The role of the physician should be to provide the patient with enough information so that they can make a medically informed decision, not to deny the patient information because it might scare them."

“PSA Testing Controversy Reignites 'Over-Screening' Debate”, Jason Kane, PBS Newshour’s “The Rundown”, Oct. 17, 2011
http://www.pbs.org/newshour/rundown/2011/10/psa-testing-controversy-reignites-over-screening-debate.html

Premarital HIV testing

- Premarital HIV testing in Illinois in 1980s

  "If we can prevent even one child from getting AIDS, we should be doing it. This is a preventable situation."
  – Gov. Thompson (1987, New York Times)

- Marriage Act amended Jan. 1, 1988
  - 22.5% decrease in marriage licenses
  - 70,846 individuals tested, 8 HIV+ cases identified
    - Prevalence of 0.011%
  - $2.5 million cost to applicants ($5 million annually)
    - Annual budget for all HIV-related activities was $3.5million
- $312,000 cost per case detected
  - $2,000 through voluntary and risk-based screening

Premarital HIV testing

- Premarital HIV testing in Illinois in 1980s

  “If we can prevent even one child from getting AIDS, we should be doing it. This is a preventable situation.”
  – Gov. Thompson (1987, New York Times)

- Law was repealed after 18 months

  The cost of premarital testing “could have purchased 160 million condoms, paid for [HIV treatment] for one year for all persons with AIDS in Illinois, or quadrupled the state expenditure on AIDS education”

  – St. Louis Post-Dispatch, 1988

- Not just should we enact a policy or not, but also what could we do instead?

Game Show Decision

- You are a contestant on the TV Game Show:

The Wheel of Money

- You have a choice between playing one of two games, which dictate your possible winning amounts

Do you choose Game A or Game B?

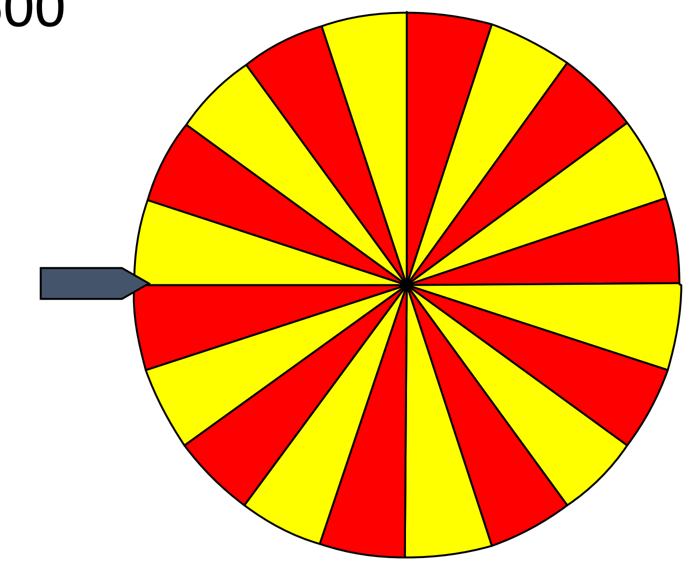
Spin the wheel and your prize depends on the game you select and the color on the wheel.

Game A

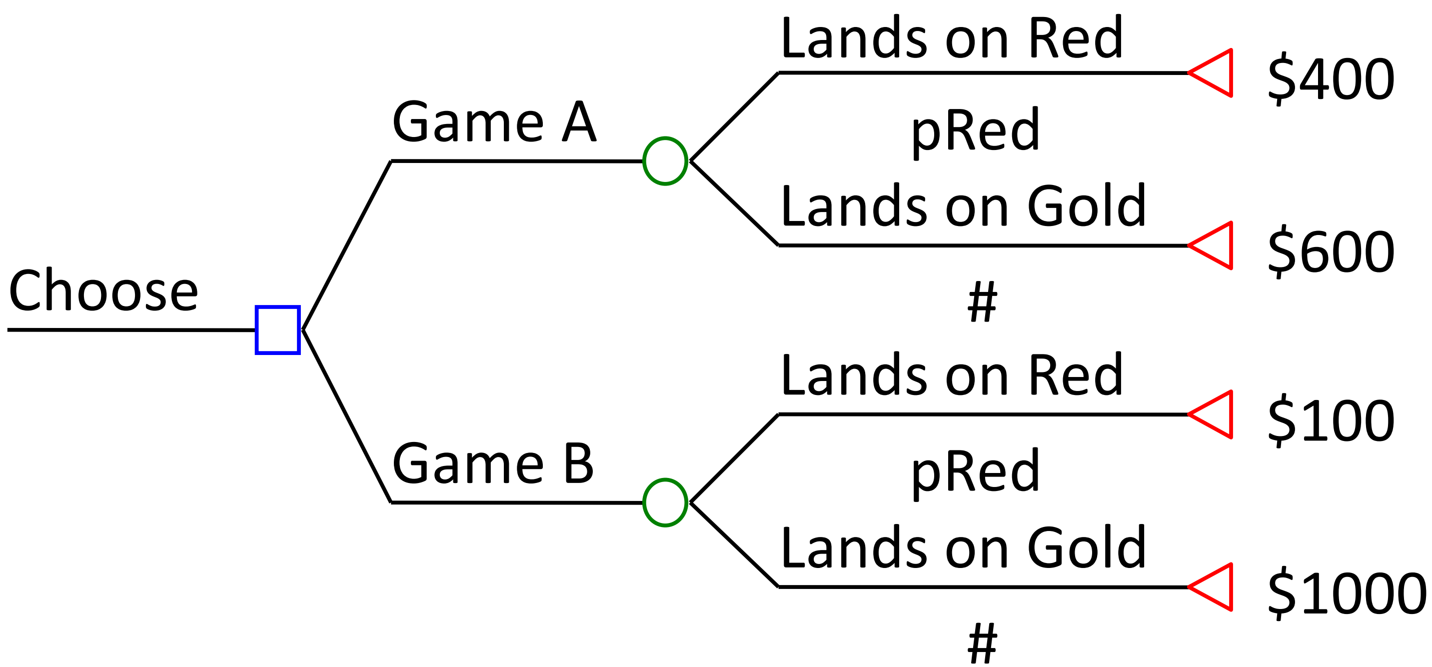
- Red=$400
- Gold=$600

Game B

- Red=$100
- Gold=$1000

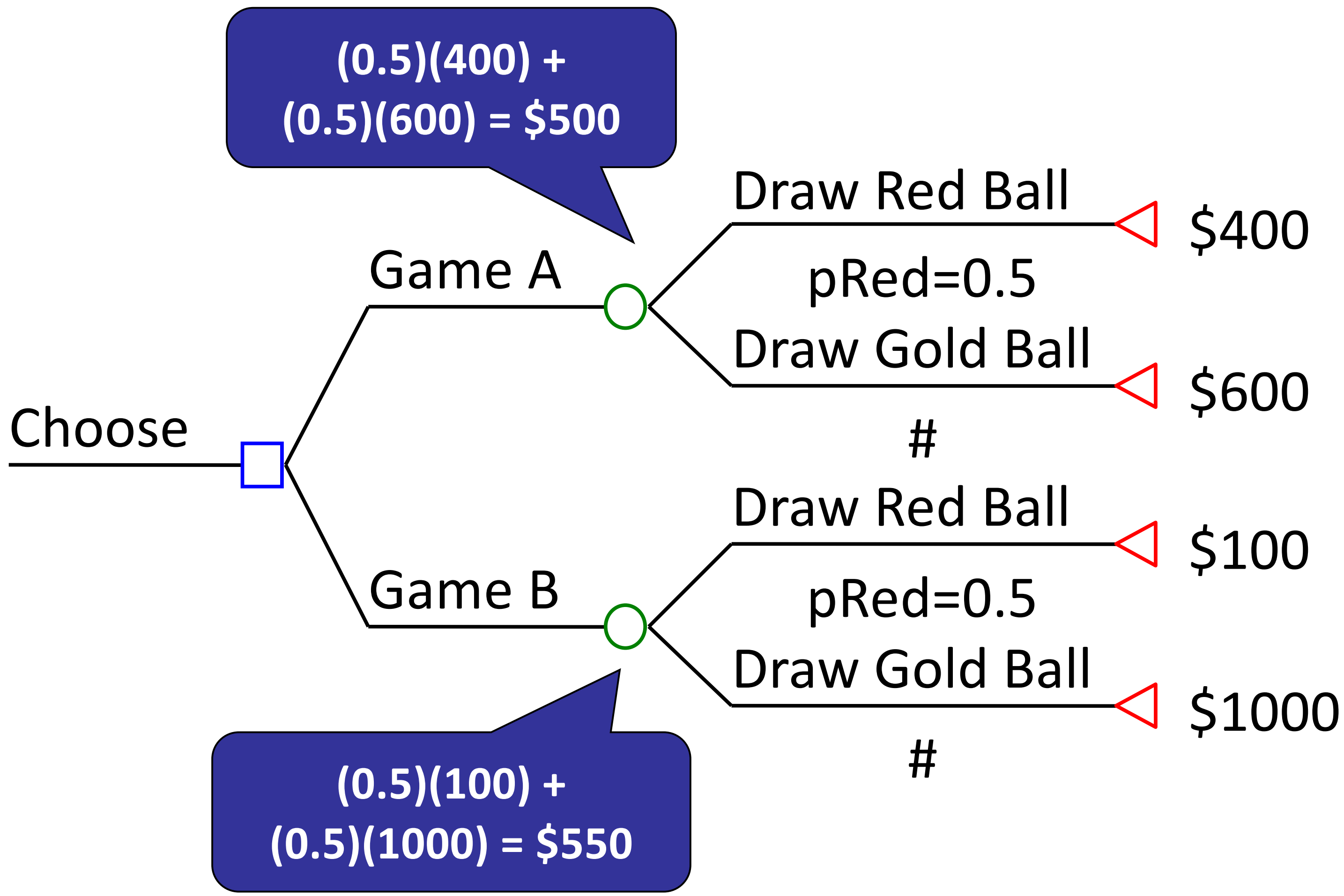


Decision Tree for Game Show



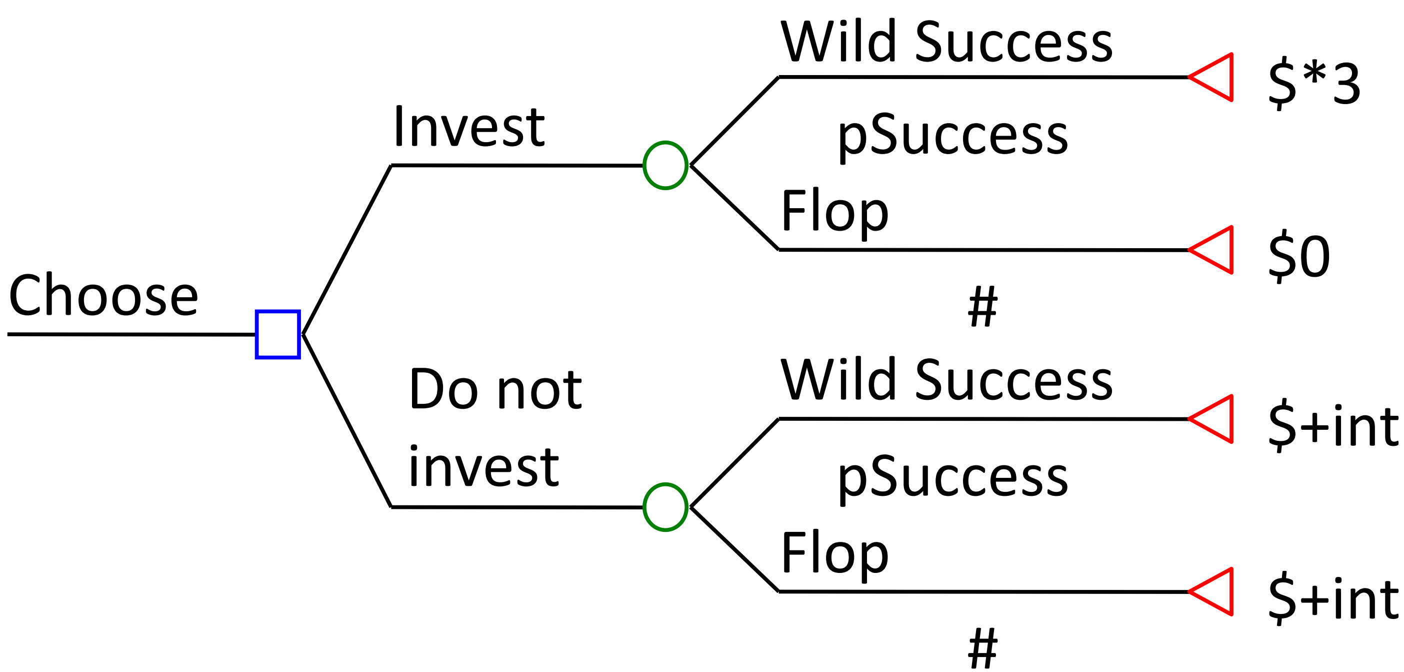
Objective: Maximize your expected winnings!

Expected Winnings



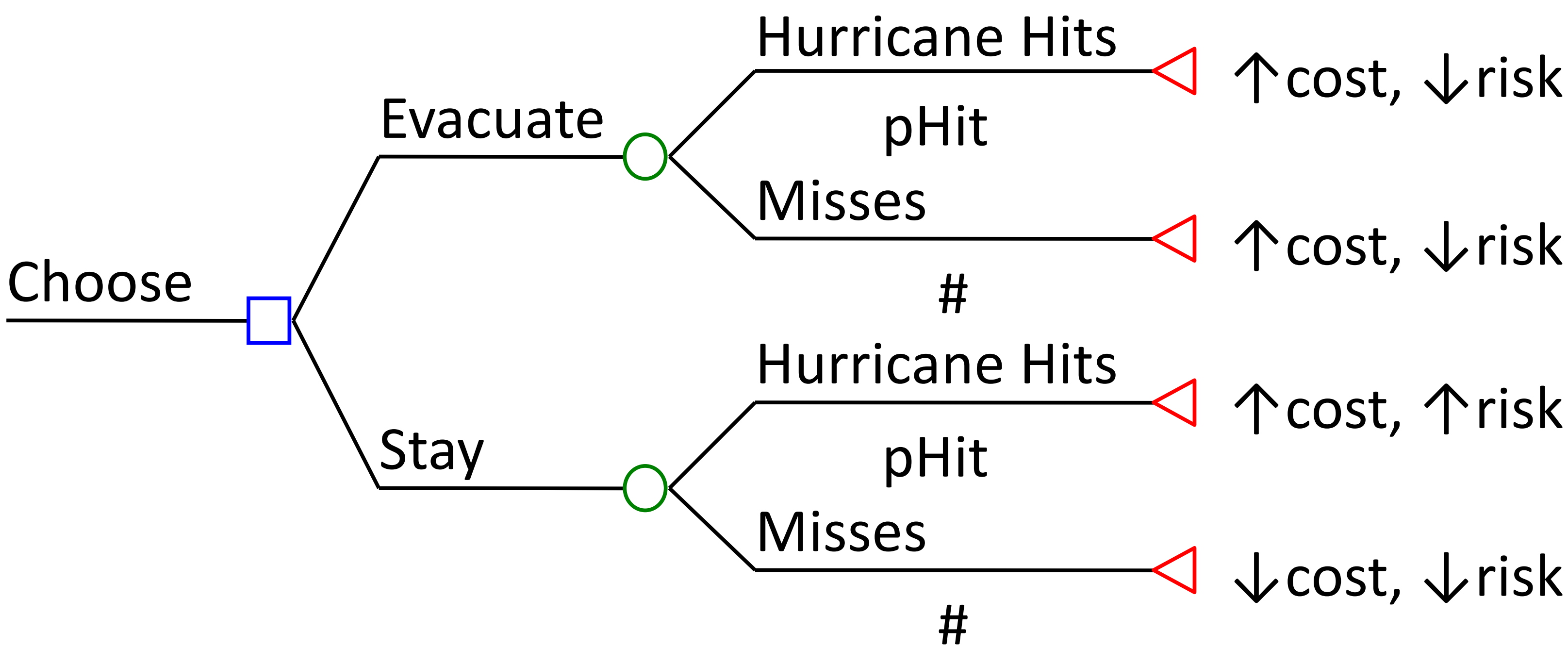
Investment Decision

Do you invest $ in a business or put it in savings?



Evacuation Decision

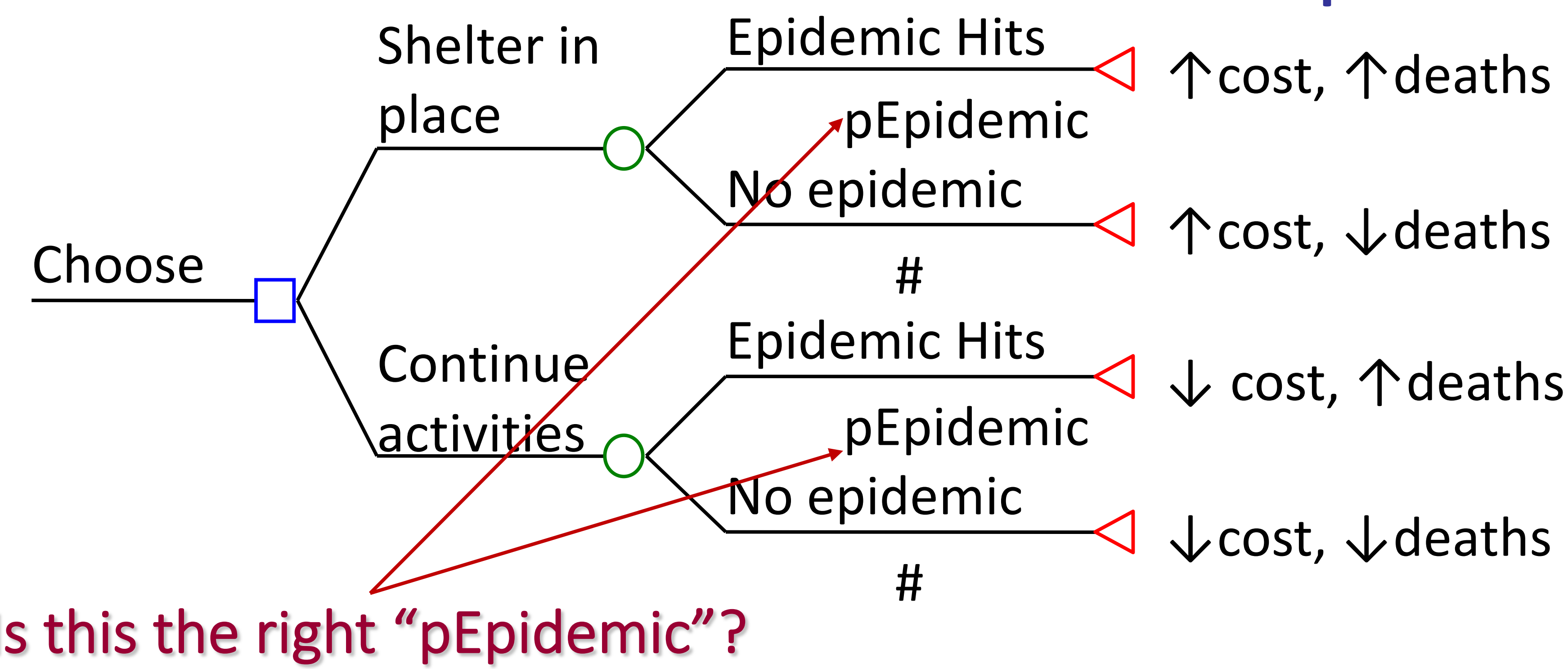
Should a community choose to evacuate if a hurricane is coming?



Sheltering-In-Place Decision

Should a <u>community</u> choose to shelter in place in the face of a world pandemic?

Should the <u>community leaders</u> choose to shelter in place in the face of a world pandemic?



Elements of Complex Decisions

- Competing options
- Uncertainty
- Risk
- Multiple competing objectives
- Unavoidable tradeoffs
- Different perspectives may lead to different conclusions

What is Decision Analysis?

- Explicit, quantitative and systematic approach to decision making under *uncertainty* (elements of statistics, economics and psychology)
- Identify, measure, and value the consequences of decisions as well as the uncertainty that exists when the decision needs to be made
- Elements are incorporated into a *model* to structure the decision problem over time, and used to compare the *expected* outcomes of different options or interventions

Models of Decision Making

- Normative
  - How *should* decisions be made?
- Descriptive
  - How *do* we make decisions?
- Prescriptive
  - Given that how we actually make decisions differs from the way we should, how can we make better decisions?

Decision Science is “decision-oriented” and not “truth-oriented”. When used in public policy, it is intended to be prescriptive, not descriptive or normative.

Steps in a Decision Analysis

1. Identify key components of the decision problem
2. Structure the problem into a logical framework over time (i.e., develop a *model*)
3. Retrieve, synthesize, and integrate data needed for the model (i.e., *parameterize* the model)
4. Conduct a base-case analysis
5. Evaluate model and parameter uncertainty

1. Key Components

- Objectives – what are the goals of the decision (e.g., minimize mortality)
- Alternatives – consider all possible options (including "do nothing")
- Events – what are the possible events that can happen?
- Outcomes – what are the consequences?

2. Structure the Problem into a Logical Framework

- *Models* are used to organize all elements of the decision problem into a logical framework, to structure the problem over time, and to represent the temporal sequence of events
- While different types of models may be chosen to accommodate the complexity of the decision problem, all rely on the use of mathematical analysis to compare the expected outcomes associated with different alternatives

3. Synthesize and Integrate Data

- Parameters are needed for all probabilities and outcomes in model.
- Use quantitative data (e.g., disease prevalence, treatment efficacy, test performance, costs, quality of life) to assign values to parameters
- Consider qualitative information (e.g., ethical issues)

4. Conduct a Base-case Analysis

- Calculate the ***expected outcomes*** associated with each option or alternative and choose the option that maximizes the valued outcome or minimizes the negative consequences
- Special case of two outcomes: cost-effectiveness analysis (maximize health or benefit within the constraints of a limited budget)

5. Evaluate Uncertainty

- Parameter uncertainty – vary each parameter within a reasonable range to examine the impact on the results (the decision)
- Model uncertainty – evaluate the impact of making structural changes to the model or changes to assumptions

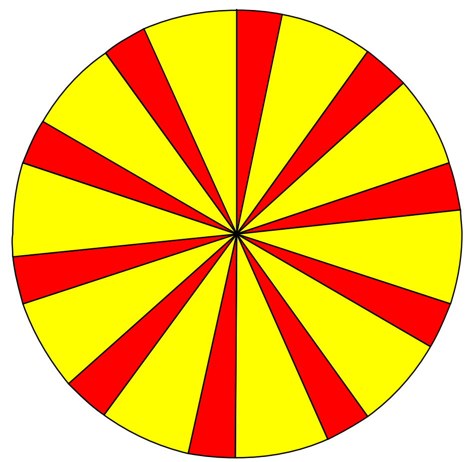
Considerations

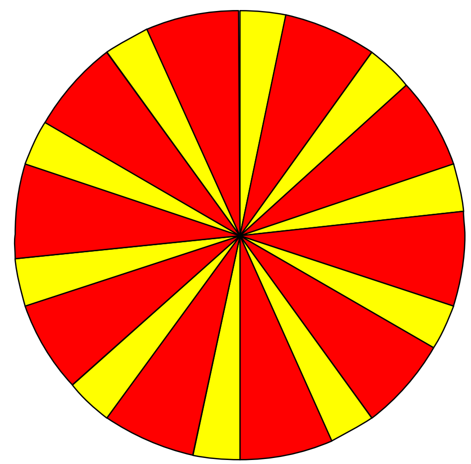
- What is the objective and who is the decision maker? (perspective)
- What are the alternatives? (action, no action, get more information)
- Does the analytical framework have face validity? (structure, probabilities, outcomes)
- Is the uncertainty adequately represented? (evidence-based, subjective probabilities, assumptions)
- Are the results placed into appropriate context? (preferences and values, risk attitudes, ethics, equity)

Game Show Revisited

Same game but now there's an equal chance that the following wheels will be used.

pRed = 1/3, 2/3





Would you pay money to take 3 sample spins (blinded) before selecting game A or B?

Rationale for Decision Scientific Approach

A decision must be made.

Probability

- A probability is a numerical estimate of the likelihood of an event.
- Probabilities range from 0 (impossible) to 1 (certain) .
- Probabilities of set of mutually exclusive and collectively exhaustive events must sum to 1.

Expected Value

- Let X be a random variable that can take N discrete values $x_1, x_2, \ldots x_n$, with their corresponding probabilities of occurrences, $\mathrm{p}(x_1), p(x_2), \ldots p(x_n)$, respectively

- The expected values (EV) is then calculated as

$$E[X] = \sum_{i=1}^{N} x_i \cdot p(x_i) = \bar{X}$$

Expected Value

- The result that is expected on average for any one decision alternative (e.g., length of life, quality of life, lifetime costs).

- Maximizing expected value is a reasonable criterion for choice given uncertain prospects; though it does not necessarily promise the best results for any one individual.

Expected Value Decision Making

- Choosing the alternative with the highest expected value does not necessarily assure that any <u>individual</u> has a better outcome than with other options
  - e.g., A patient given treatment A may still die before another patient given treatment B.
- The <u>average</u> outcome for <u>many</u> individuals will be best if the alternative with the highest expected value is chosen
  - e.g., on average, patients given treatment A will live 0.40 years longer than patients given treatment B.

Outbreak of a Mosquito-Borne Virus

- An outbreak of encephalitis, caused by a mosquito-borne virus, has been reported. The Department of Health in a nearby city (population: 100,000) must decide whether they should spray with pesticide, not spray with pesticide, or get more information.
- We know from prior patterns of epidemics that the probability of an encephalitis outbreak of this nature in this general location of the country is 20%. The outbreak would result in 2% of the city's population developing encephalitis over two weeks. Of those affected, 30% will die, and the remaining 70% will recover with no long-term problems.

Outbreak of a Mosquito-Borne Virus

- If the city sprays, only 0.1% of the population will develop encephalitis over 2 weeks, if an outbreak occurs. But the pesticide is toxic, causing a fatal illness in 0.1% of exposed individuals. (Assume those who survive encephalitis are not at risk of dying due to pesticide toxicity.)
- If the city opts to test, it can learn with certainty whether an outbreak will occur. However, testing takes 1 week, during which time 1% of the population would become infected in the event of an outbreak, even with delayed spraying. **Note that there will still be a benefit of spraying but that it will be a reduced benefit because of the delay of one week.**

Outbreak of a Mosquito-Borne Virus

- The DH is in a rush to make the decision because if there is an epidemic, spraying immediately reduces the impact of the outbreak. However, there are negative consequences to spraying if there is no outbreak.
- Are the potential benefits of spraying enough to outweigh the potential risks of the pesticide? Is the test worth the delay?

Decision Making Without Analysis

- Goal: Minimize the number of deaths in the city
- The DH has all the information it needs to make a decision.
- What's the best option?

Steps

1. Structure the problem
2. Build the tree
3. Conduct the base-case analysis
4. Conduct sensitivity analysis

Step 1: Structure the Problem

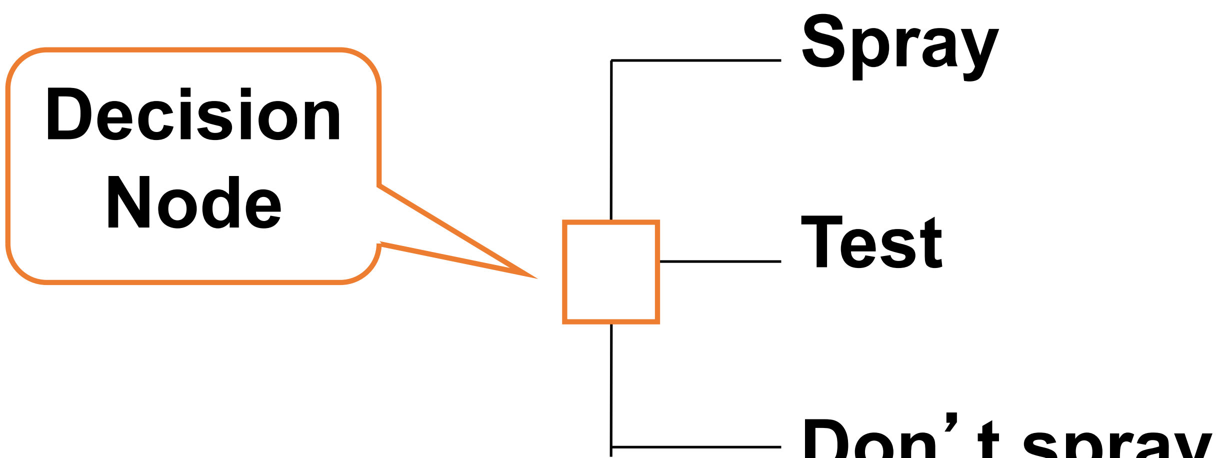
- Describe the decision problem and starting point
- Choose a time horizon
- Identify the decision alternatives
- Identify the probabilities
- Specify the valued outcome(s)

Starting Point and Time Horizon

- **Starting point**
  - City with potential encephalitis outbreak (population: 100,000)
- **Time horizon**
  - 2 weeks

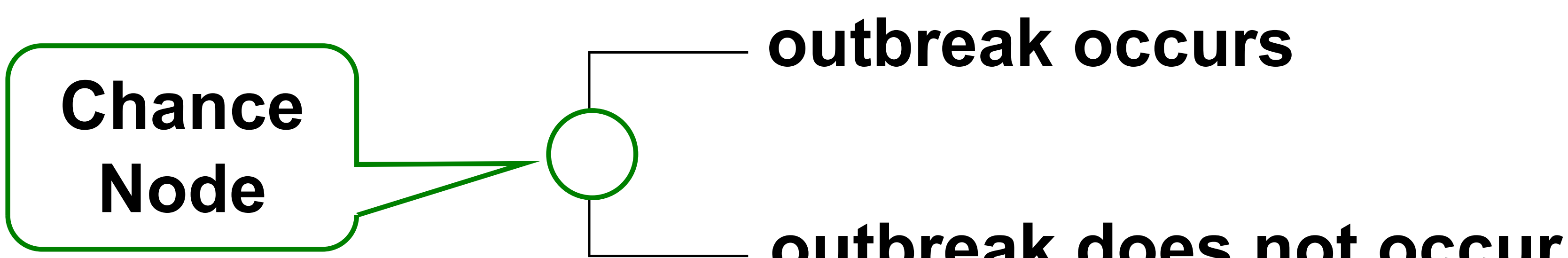
Decision Alternatives

- Action: Spray vs. Don’t Spray
- Information: Test vs. No Test



Probabilities

- Outbreak occurs (p=0.20)
- Develop encephalitis if there is an outbreak and you did not spray (p=0.02)
- Die if develop encephalitis (p=0.30)



More Probabilities

- Develop encephalitis if there is an outbreak and you did spray (p=0.001)
- Develop encephalitis if there is an outbreak and you did spray, but you waited one week to get perfect information before going ahead with the decision (p=0.01)
- Die from toxicity if spraying occurs (p=0.001)

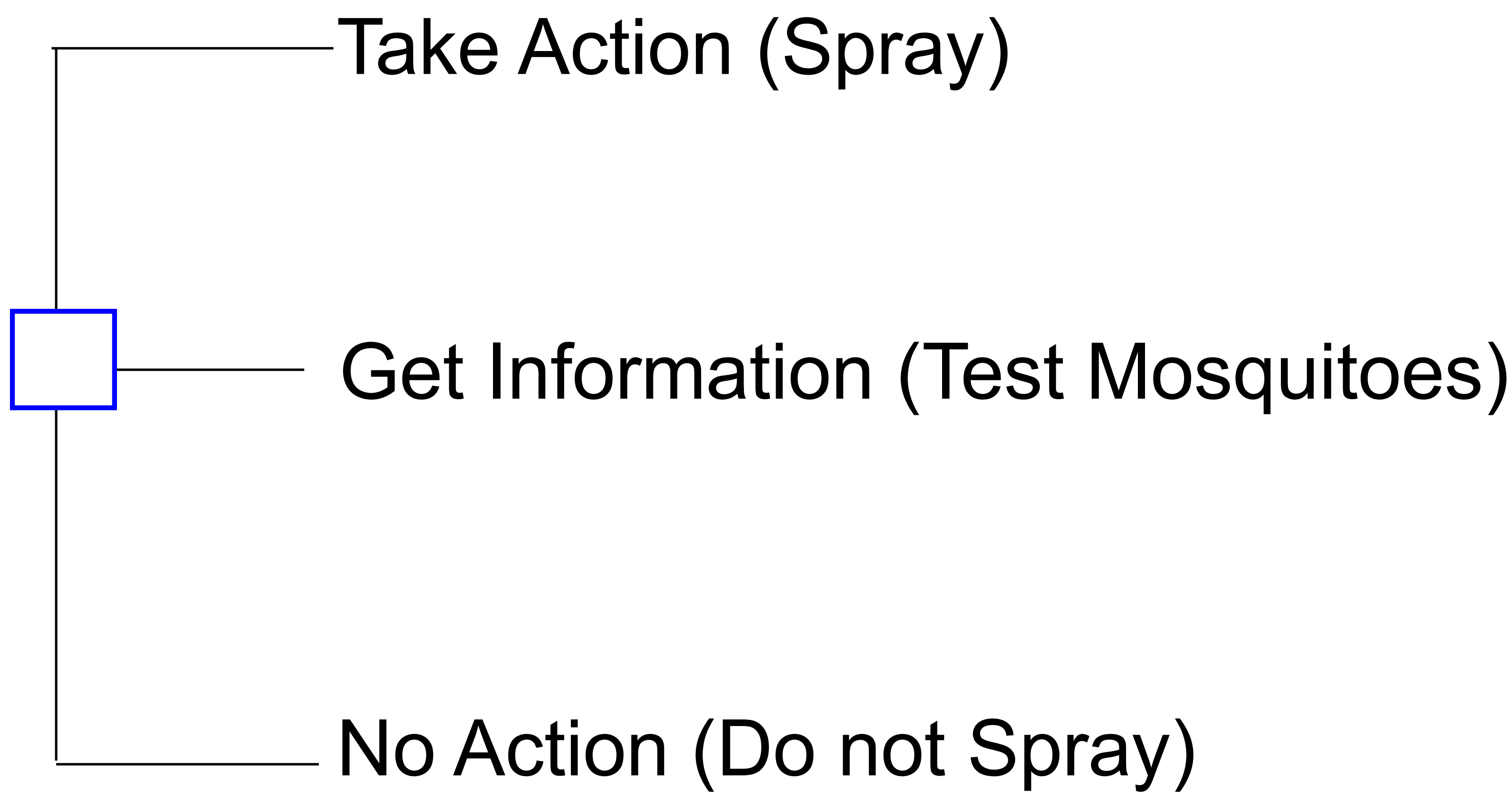
Outcomes and Values

- Two possible outcomes
  - Dead
  - Alive
- Objective: Minimize the number of deaths, on average, in the city (find the lowest expected value)
- Assign values of 1 for "Dead" and 0 for "Alive"

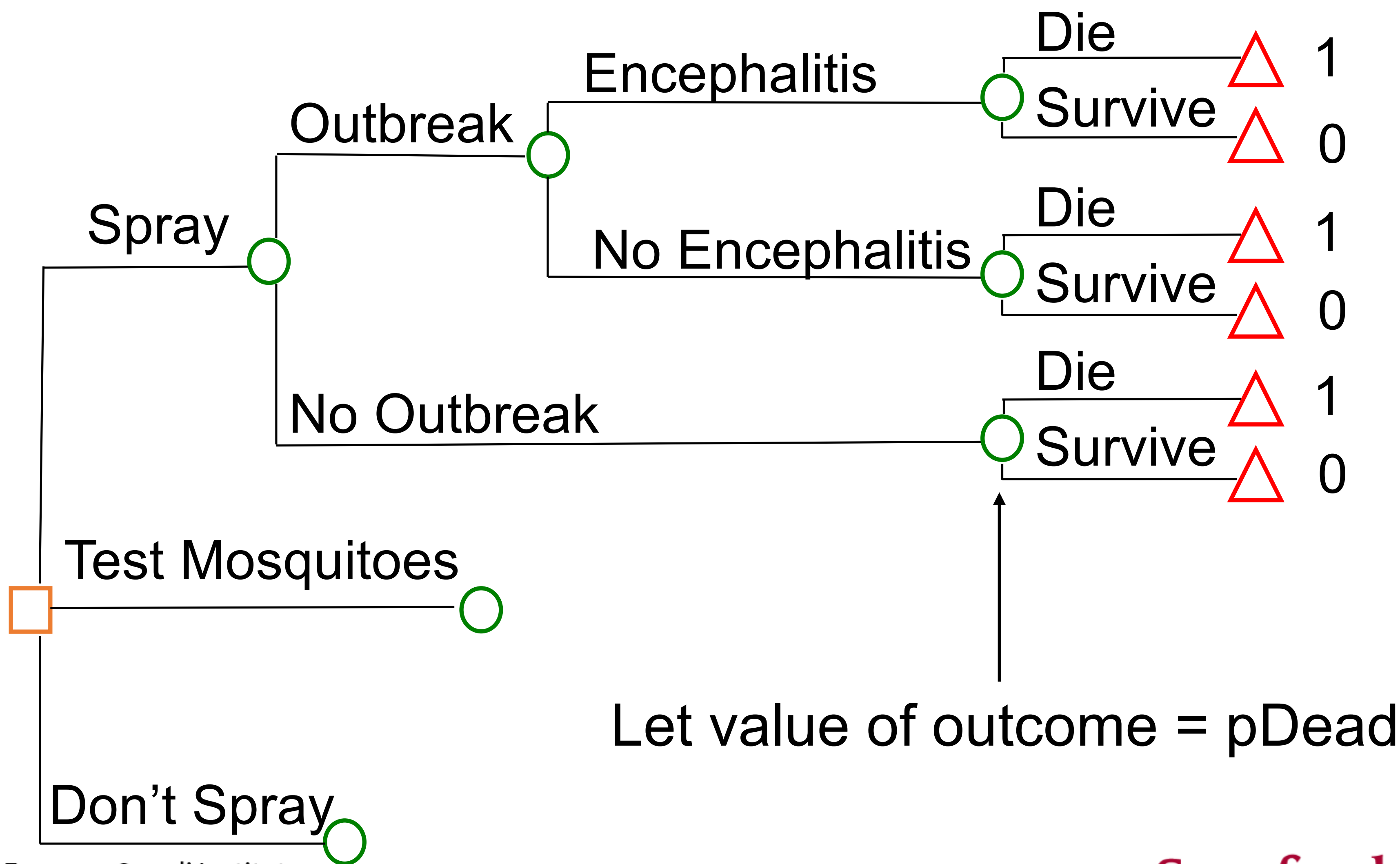
Step 2: Build the Tree

- Represent the sequence of events leading to outcomes
- Estimate the probability of each event at each chance node
- Assign a value to each possible outcome

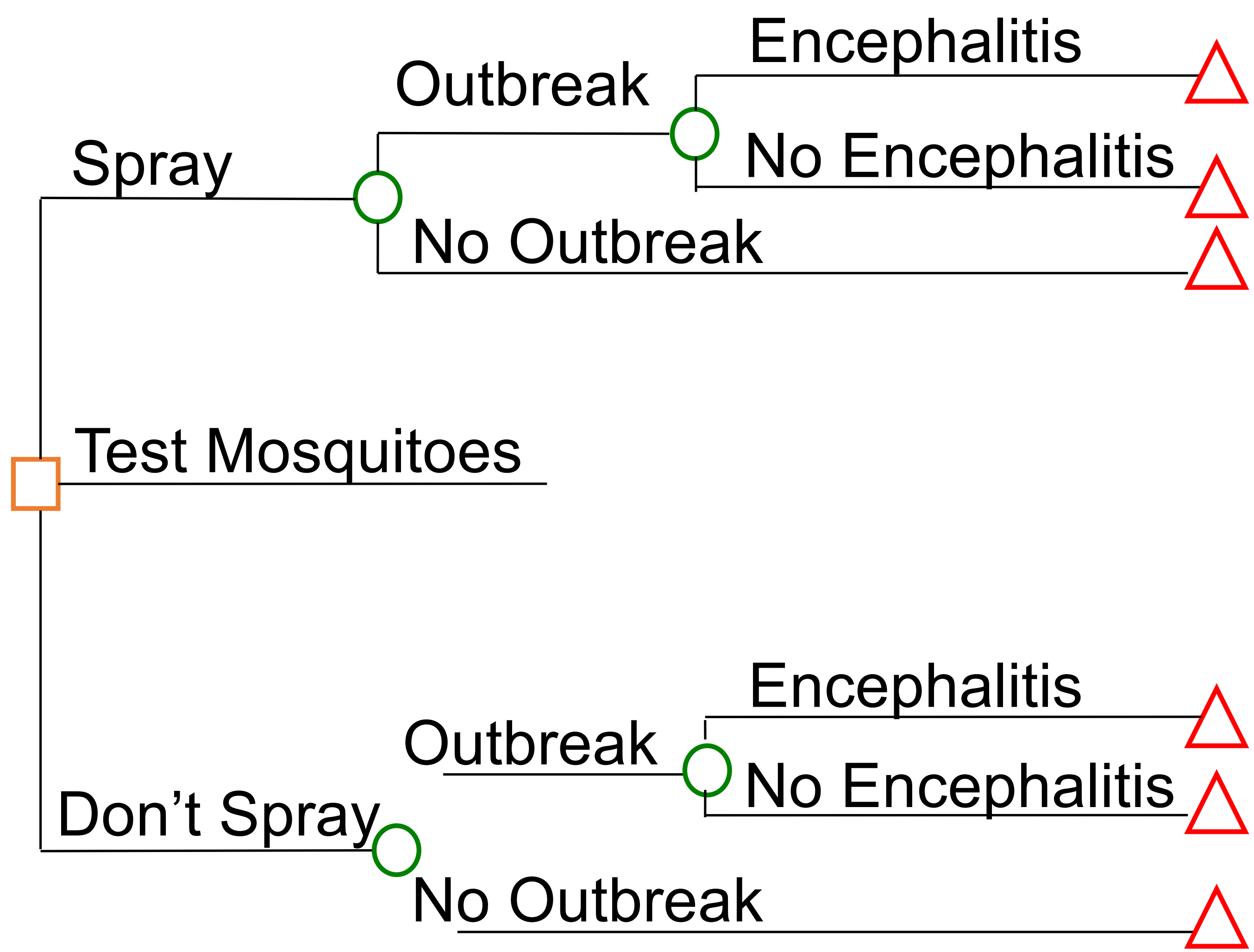
Alternatives: branches off decision node (strategic form)



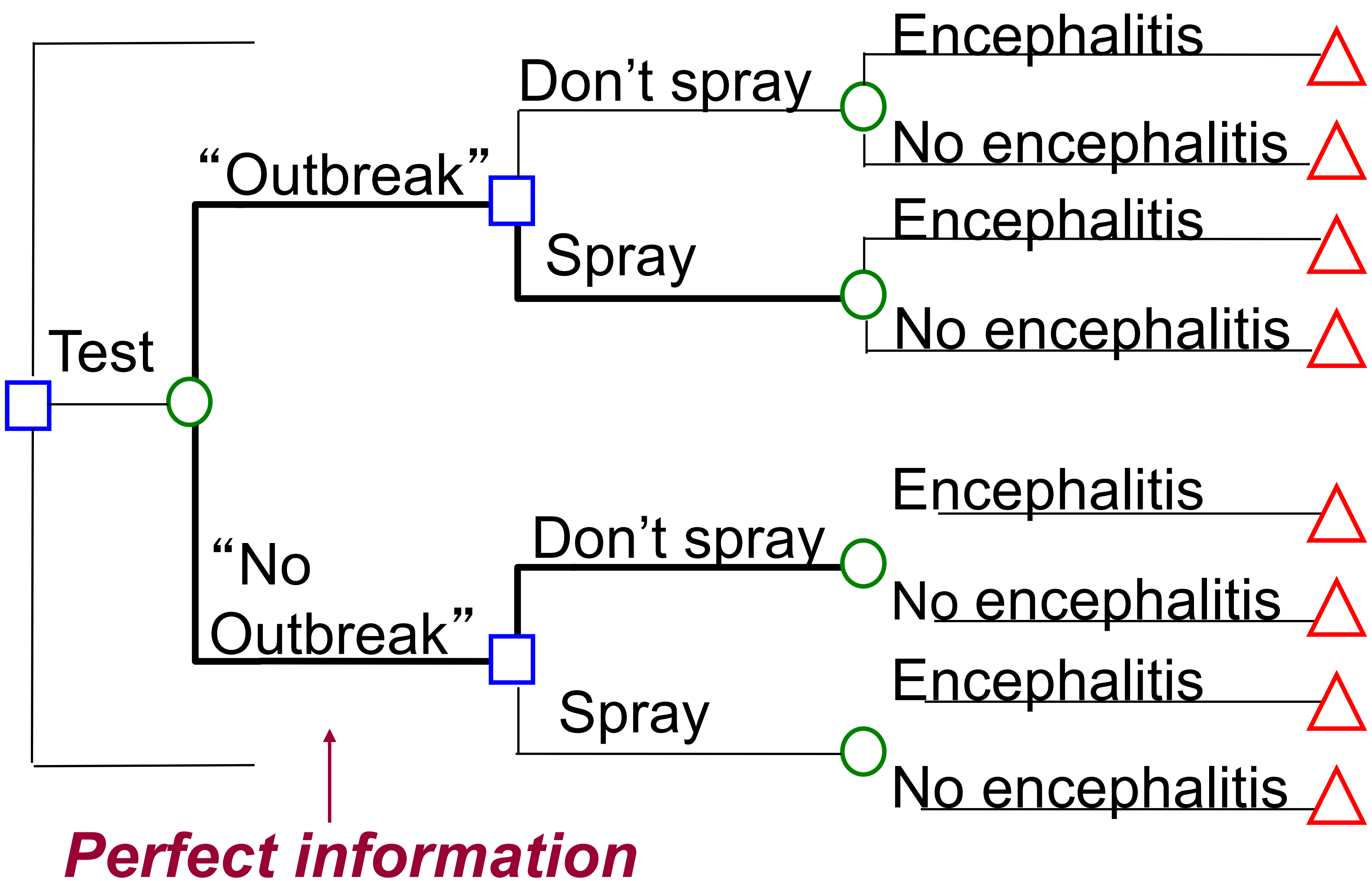
What can happen if we spray?



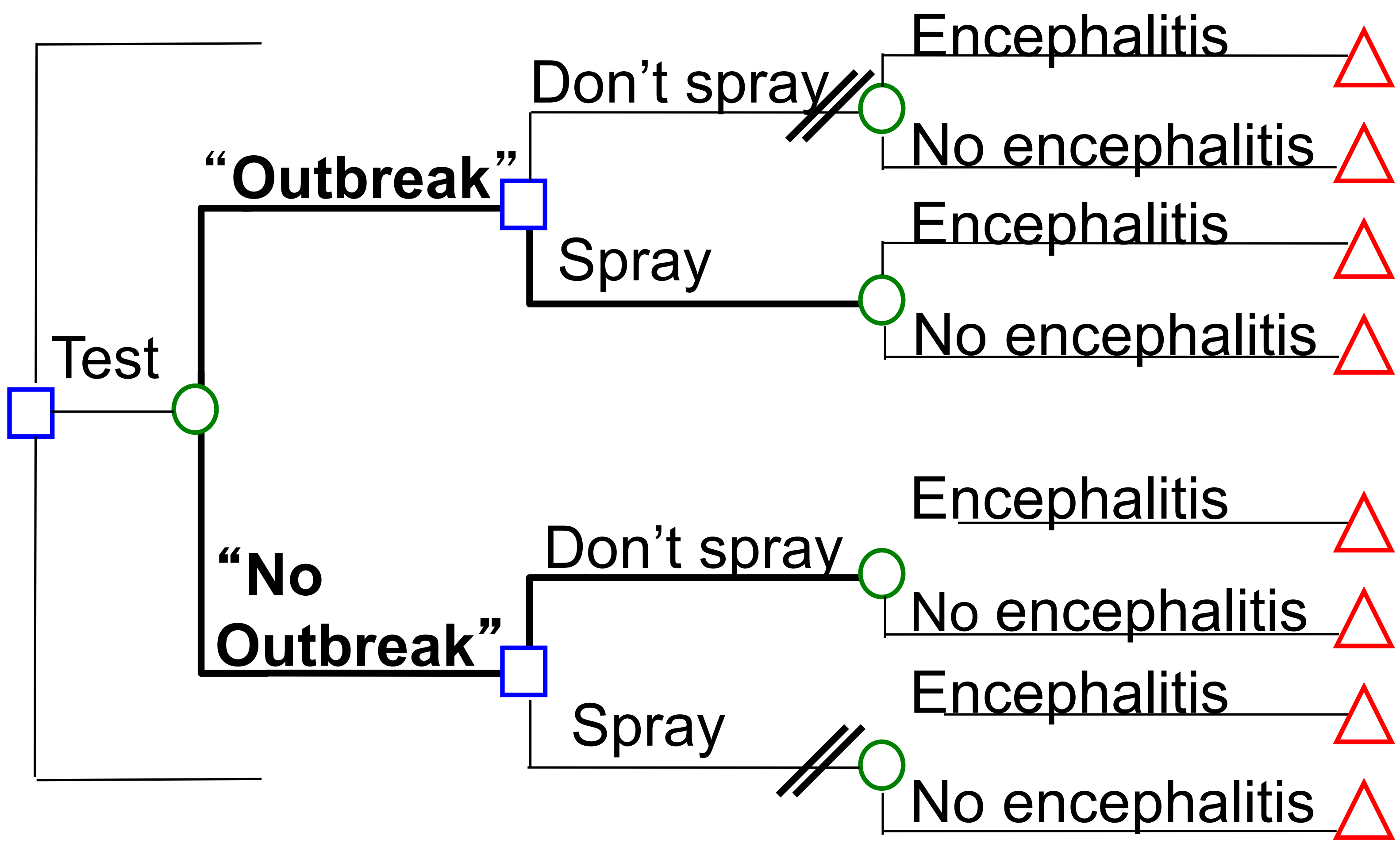
If we don't spray…



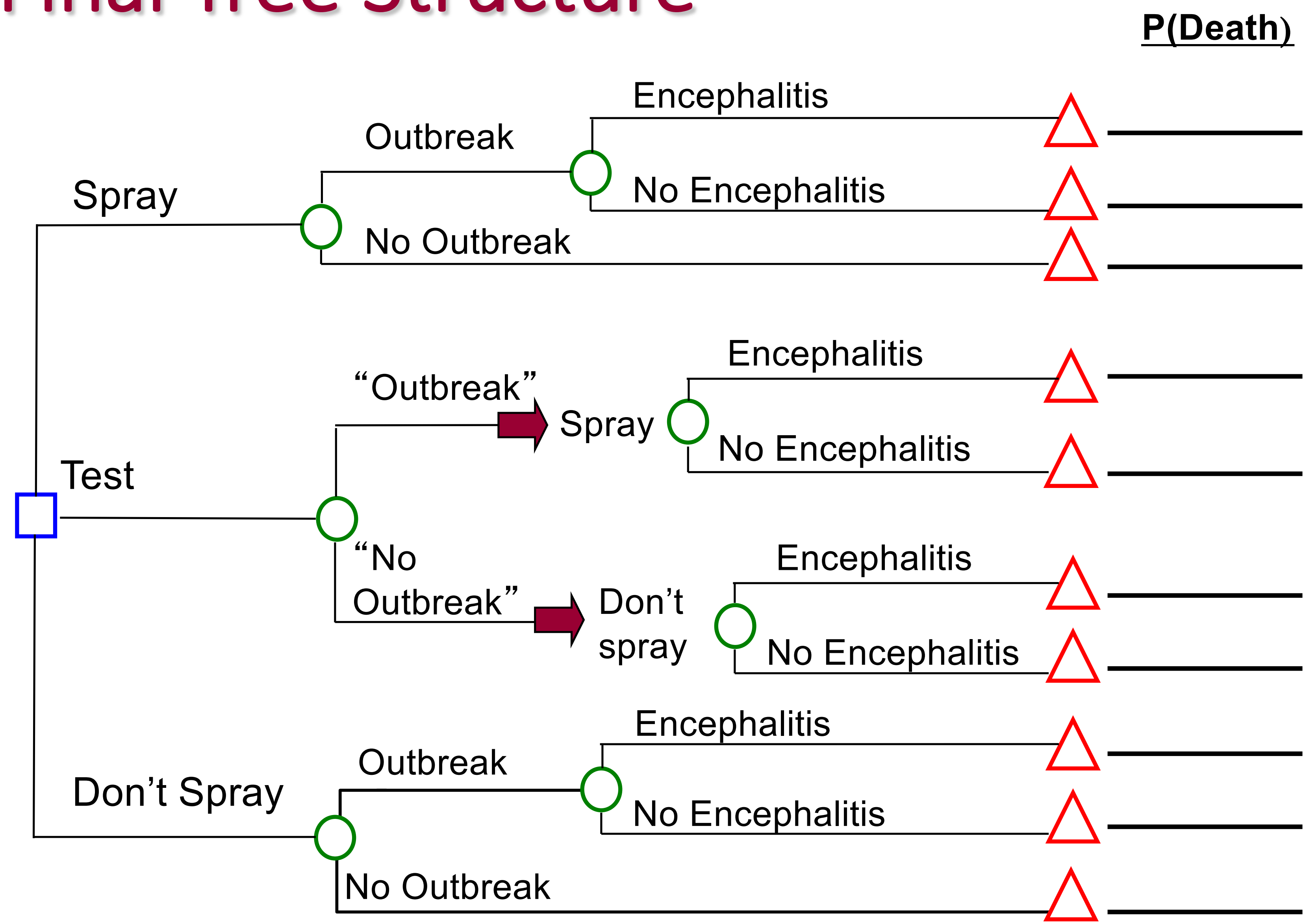
The Test Strategy



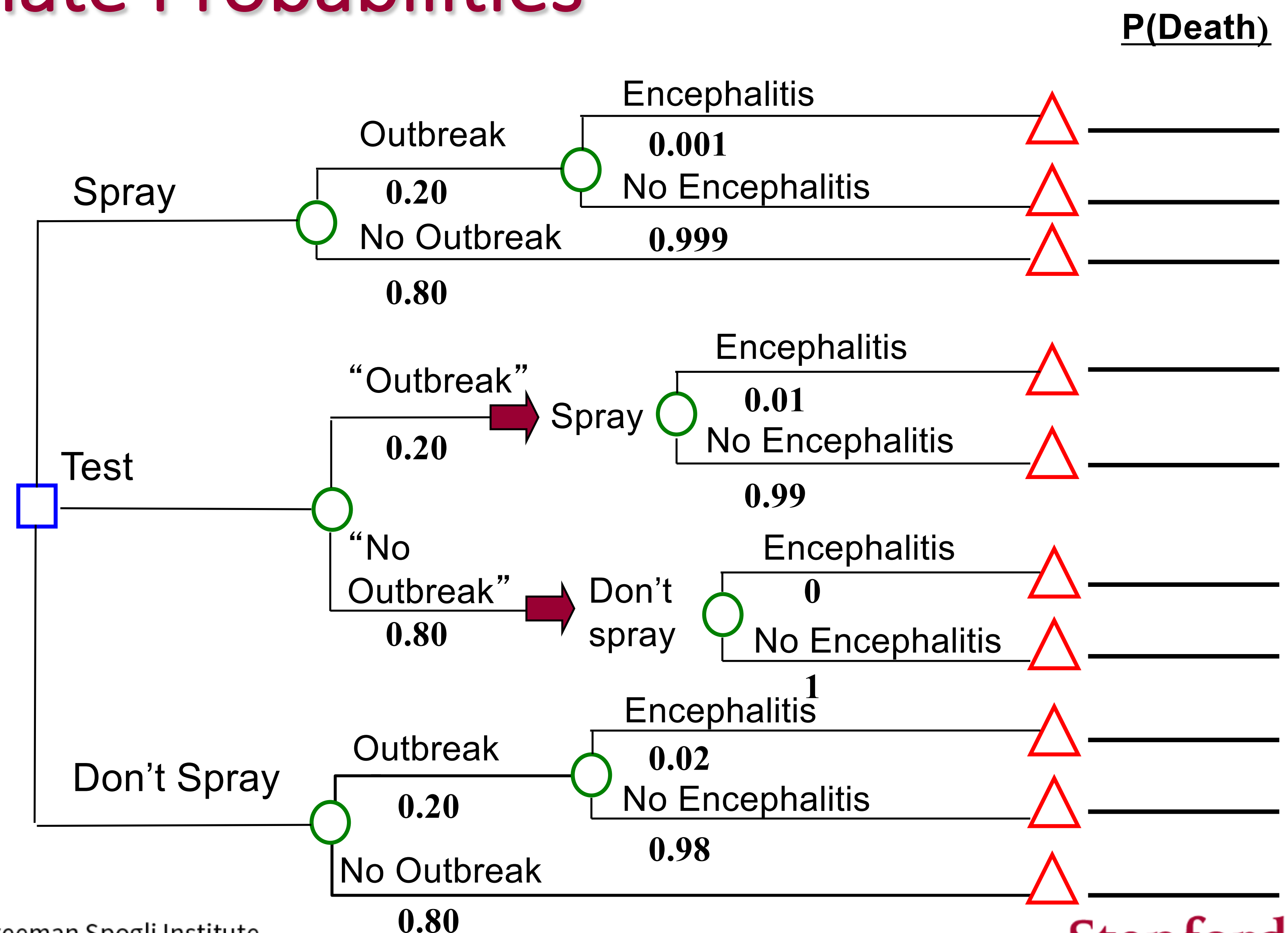
Pruning the Tree



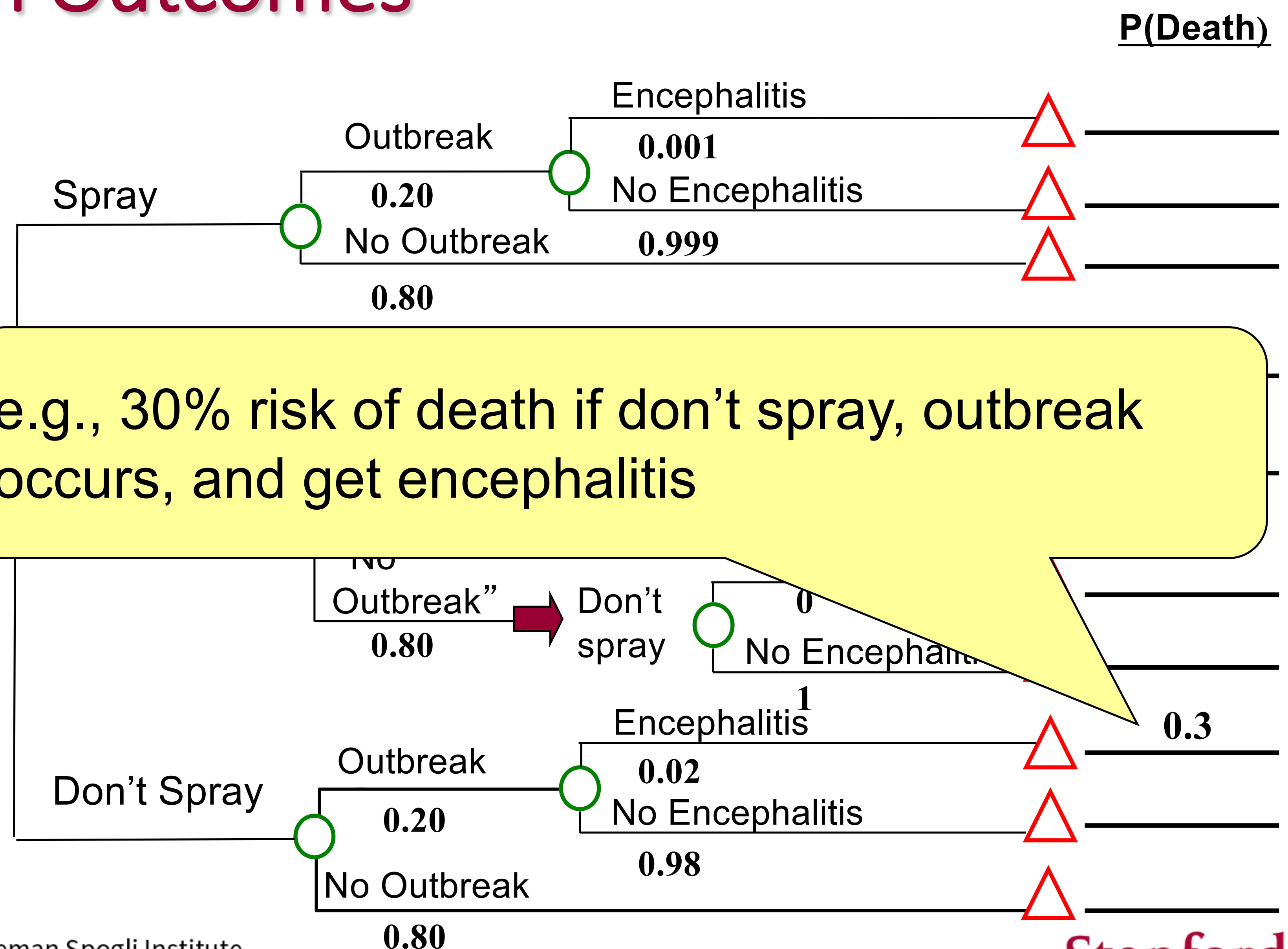
The Final Tree Structure



Estimate Probabilities

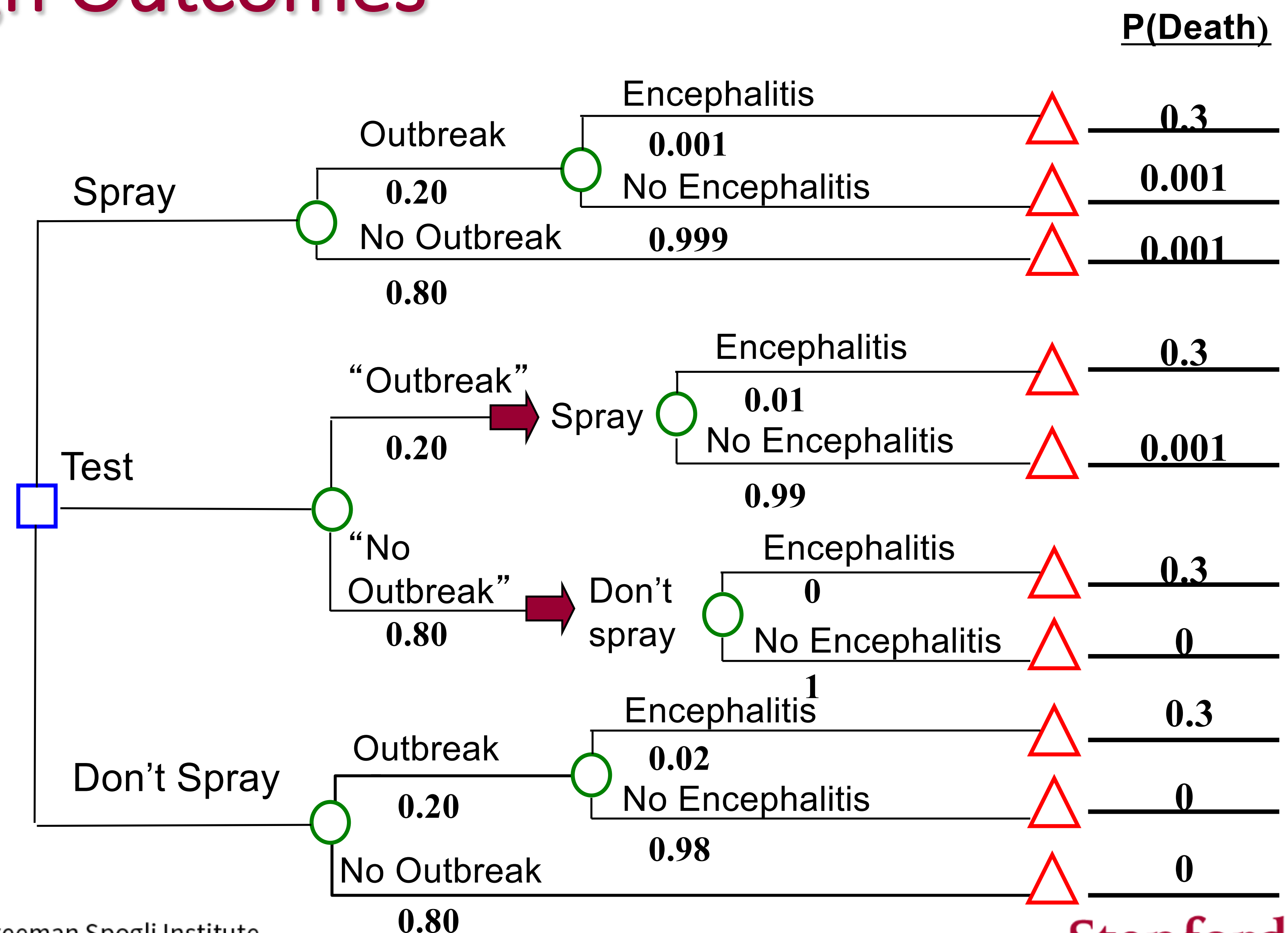


Assign Outcomes

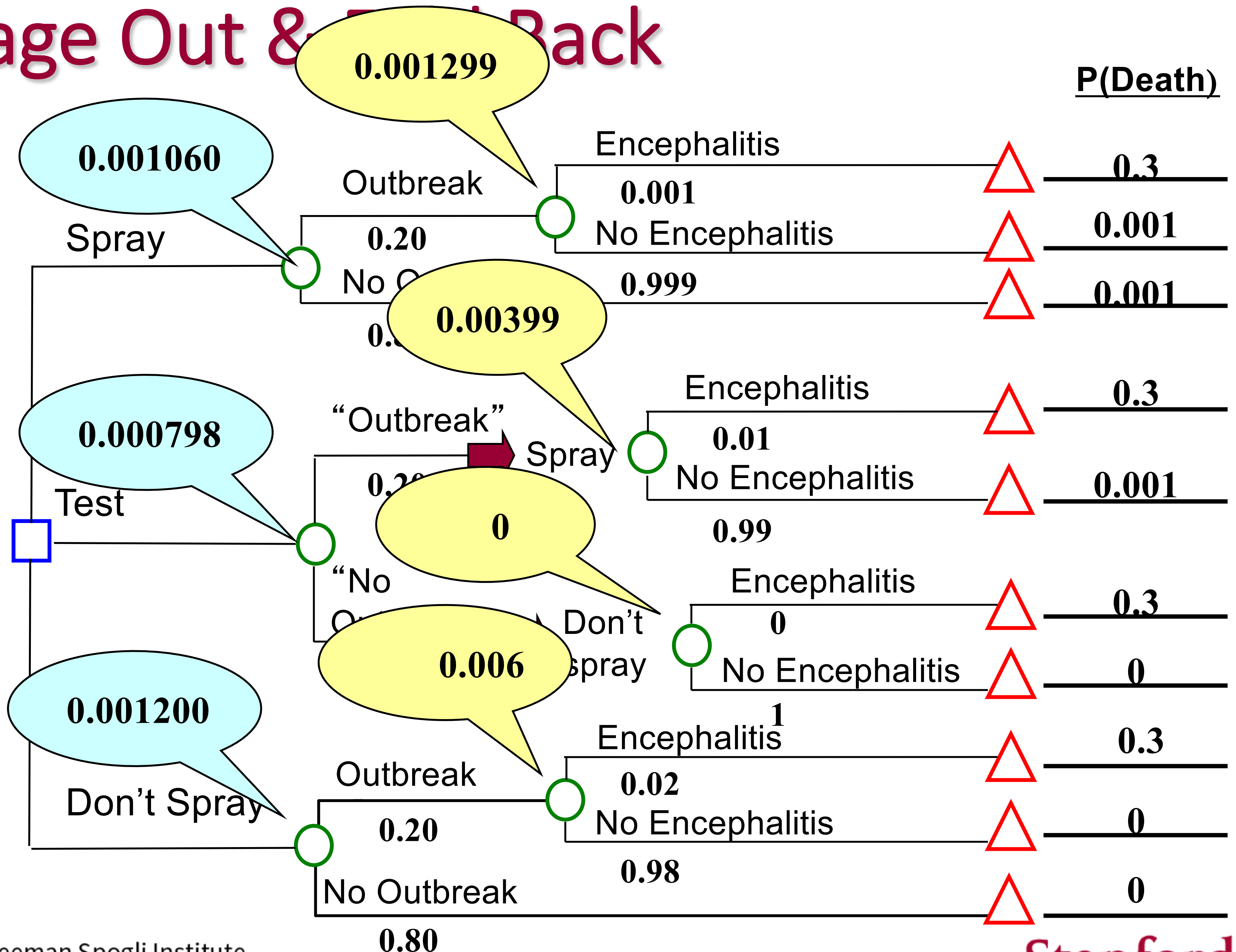


e.g., 30% risk of death if don't spray, outbreak occurs, and get encephalitis

Assign Outcomes



Average Out & Fold Back



Step 3: Base-Case Analysis

- Convert probability of death into expected number of deaths based on the city's population of 100,000:

Strategy	Expected # of deaths
Spray	106
Test	80
No Spray	120

Step 4: Conduct Sensitivity Analysis

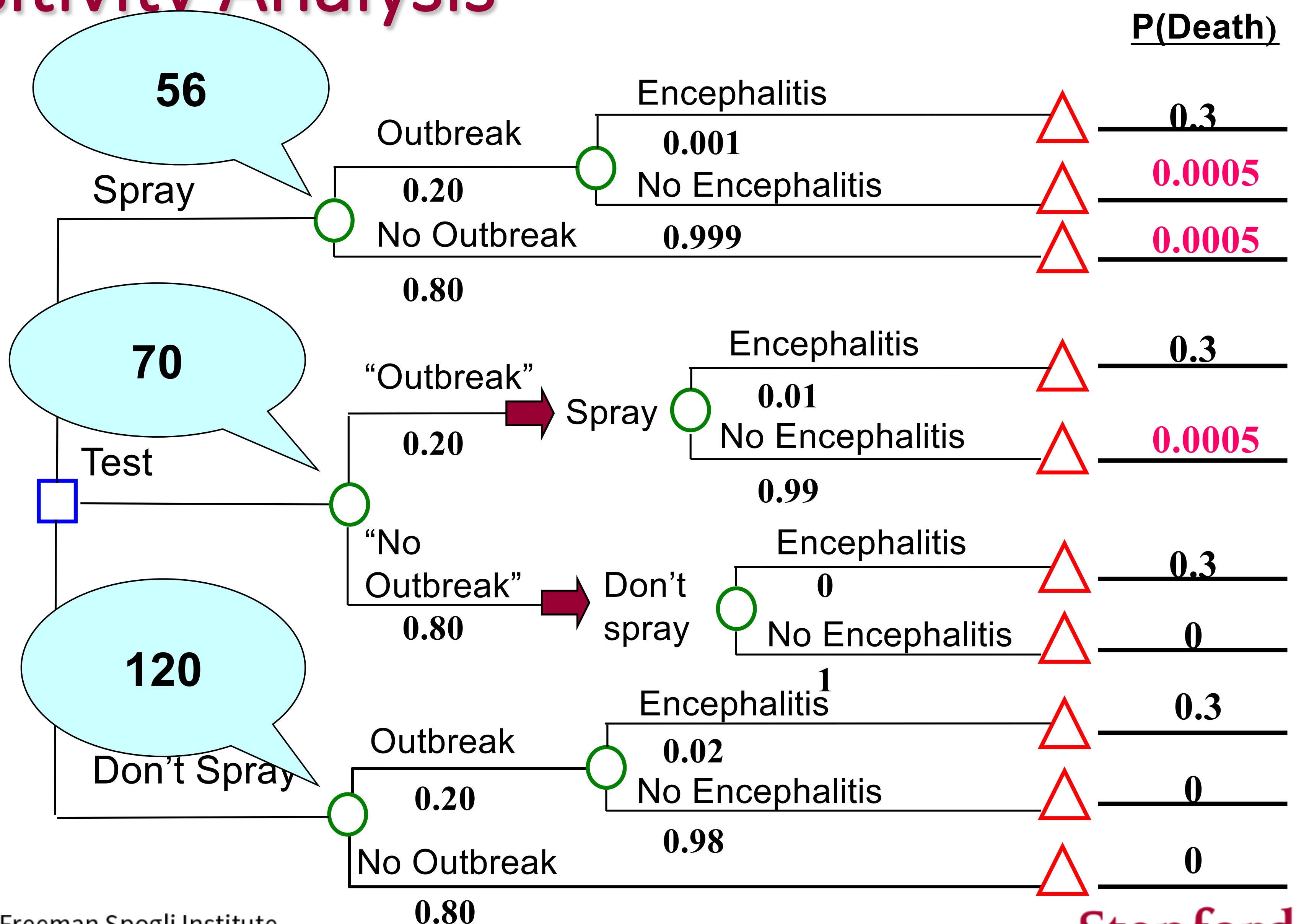
- One-way sensitivity analysis
- Two-way sensitivity analysis (introduced later)
- Threshold analysis

Toxicity of Spraying

- What if the risk of death due to pesticide toxicity can be reduced by 50% if people stay inside during spraying?

- Replace probability of death due to pesticide toxicities p=0.001 with p=0.0005 and average out and fold back again.

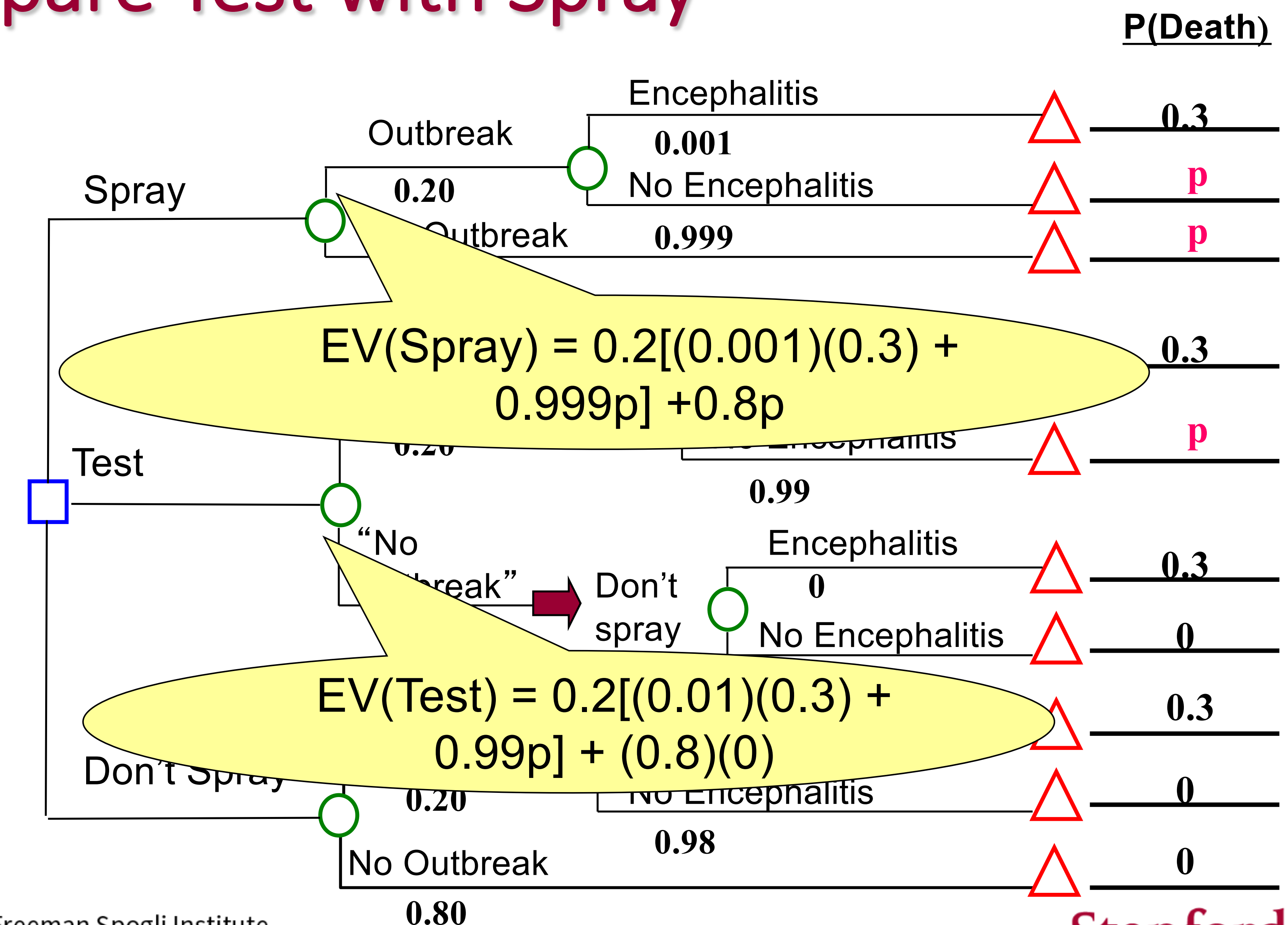
Sensitivity Analysis



Threshold Analysis

- Identify relevant pairs of strategies to compare
- Identify the uncertain parameter of interest (e.g., risk of death due to toxicity)
- Determine the value of the parameter such that the expected value of the two strategies is equal (e.g., solve for the value of the parameter)
- Interpret this ‘threshold’ value

Compare Test with Spray



Test – Spray Threshold

- Consider probability of death due to pesticide toxicity as the parameter of interest (**p**)

$$EV(Test) = 0.0006 + 0.198p$$

$$EV(Spray) = 0.00006 + 0.9998p$$

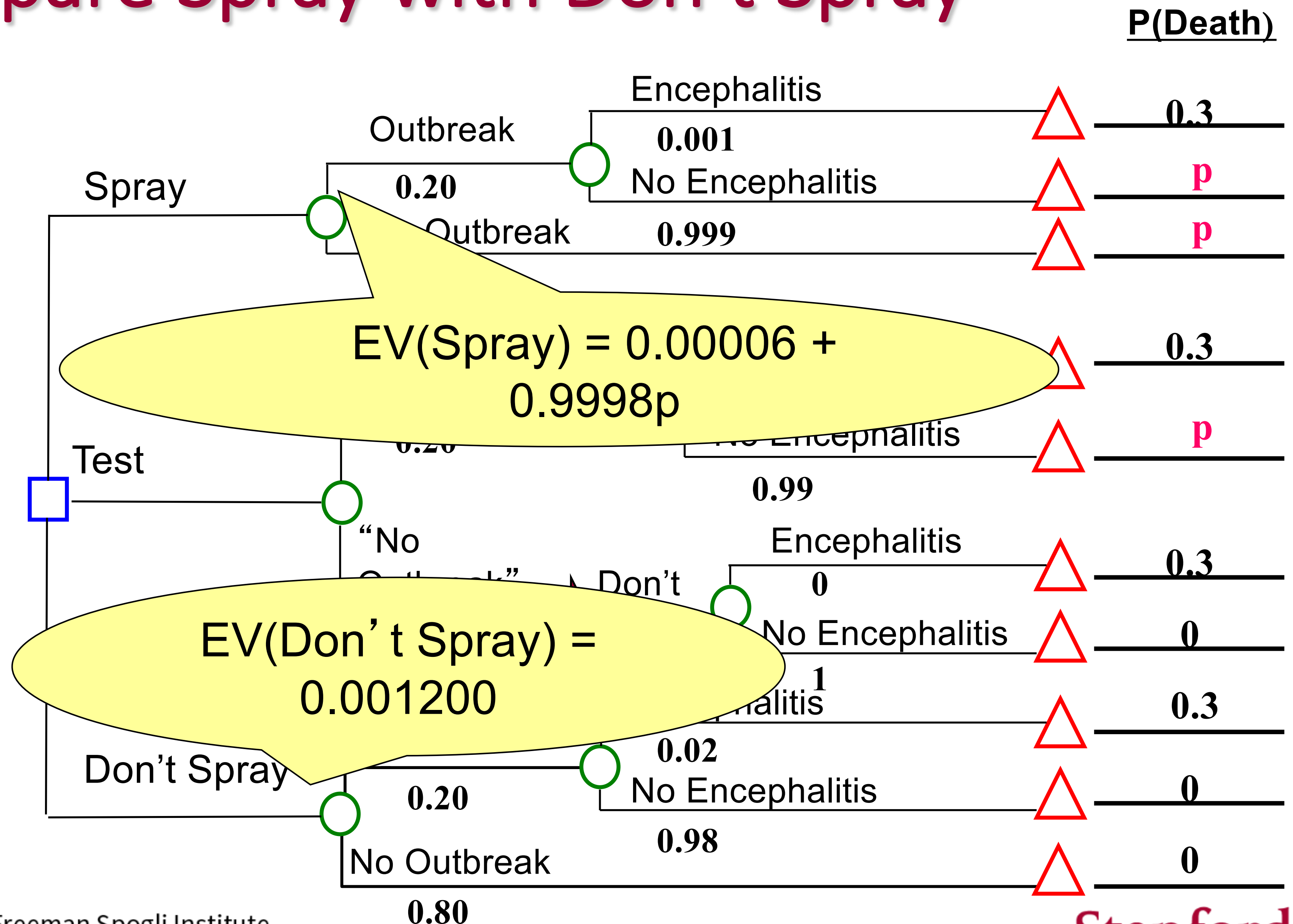
$$0.00006 + 0.198p = 0.0006 + 0.198p$$

$$\mathbf{p = 0.00067}$$

If p>0.00067, we prefer 'Test' to 'Spray'

If p<0.00067, we prefer 'Spray' to 'Test'

Compare Spray with Don’t Spray



Spray – Don’t Spray Threshold

EV(Spray) = 0.00006 + 0.9998p

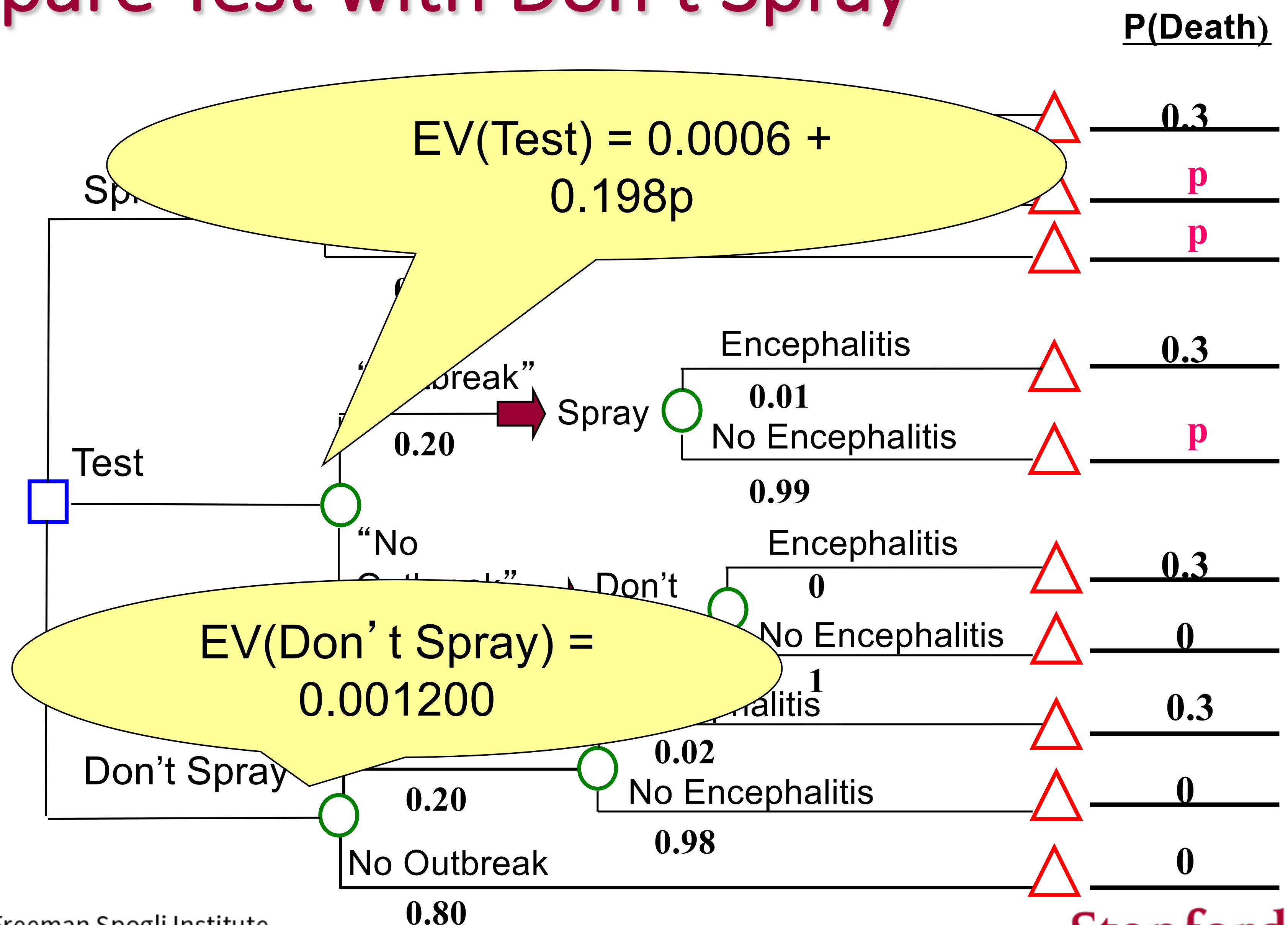
EV(Don’t Spray) = 0.0012

$$0.00006 + 0.9998p = 0.0012$$

p = 0.00114

If p>0.00114 we prefer ‘Don’t spray’ to ‘Spray’
If p<0.00114 we prefer ‘Spray’ to ‘Don’t Spray’

Compare Test with Don’t Spray



Test – Don't Spray Threshold

EV(Test) = 0.0006 + 0.198p

EV(Don't Spray) = 0.0012

$$0.0006 + 0.198p = 0.0012$$

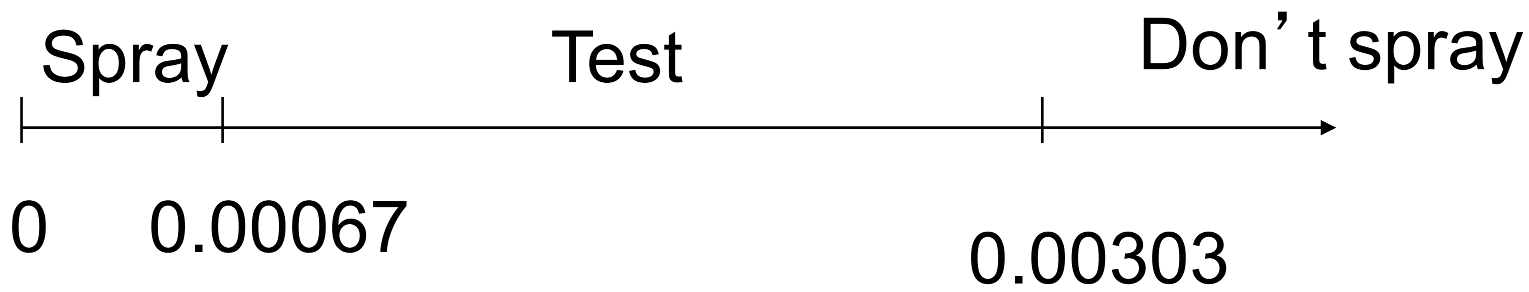
p = 0.00303

If p>0.00303 we prefer 'Don't Spray' to 'Test'

If p<0.00303 we prefer 'Test' to 'Don't Spray'

Interpret the Thresholds

p = risk of death due to pesticide toxicity

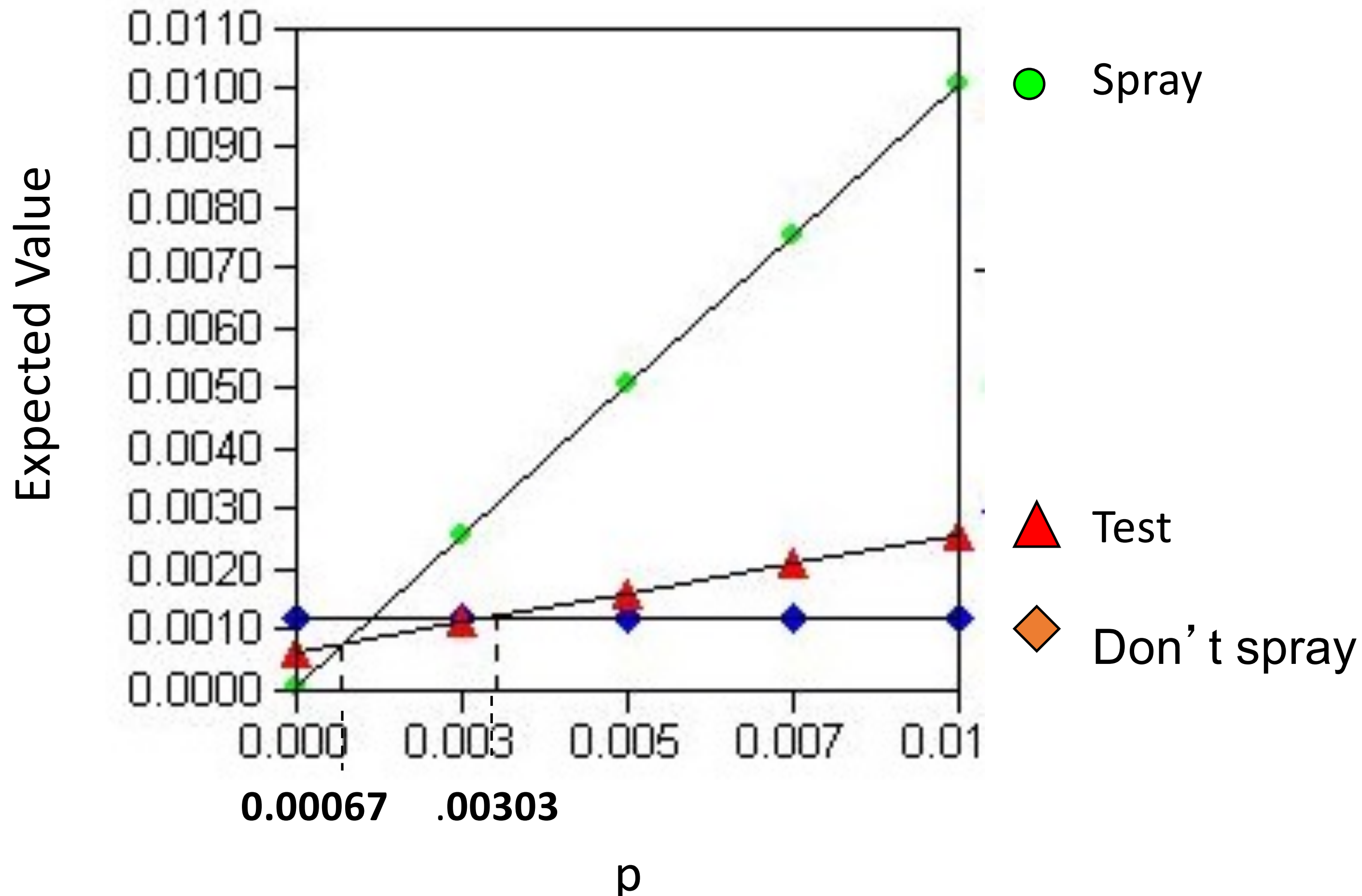


If $p < 0.00067$ ⟶ Spray

If $0.00067 < p < 0.00303$ ⟶ Test

If $p > 0.00303$ ⟶ Don’t spray

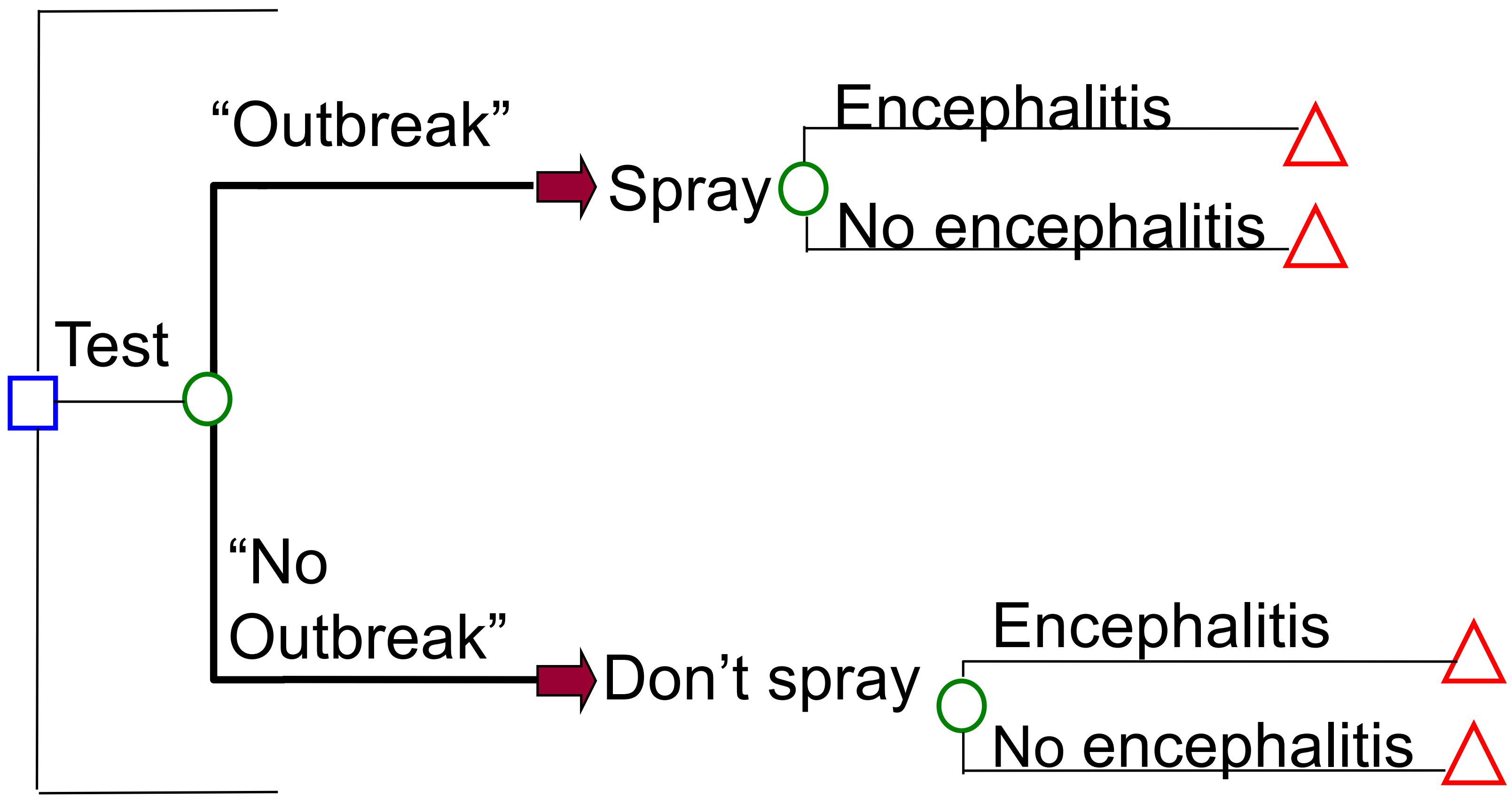
Graphical Representation of Sensitivity/Threshold Analyses



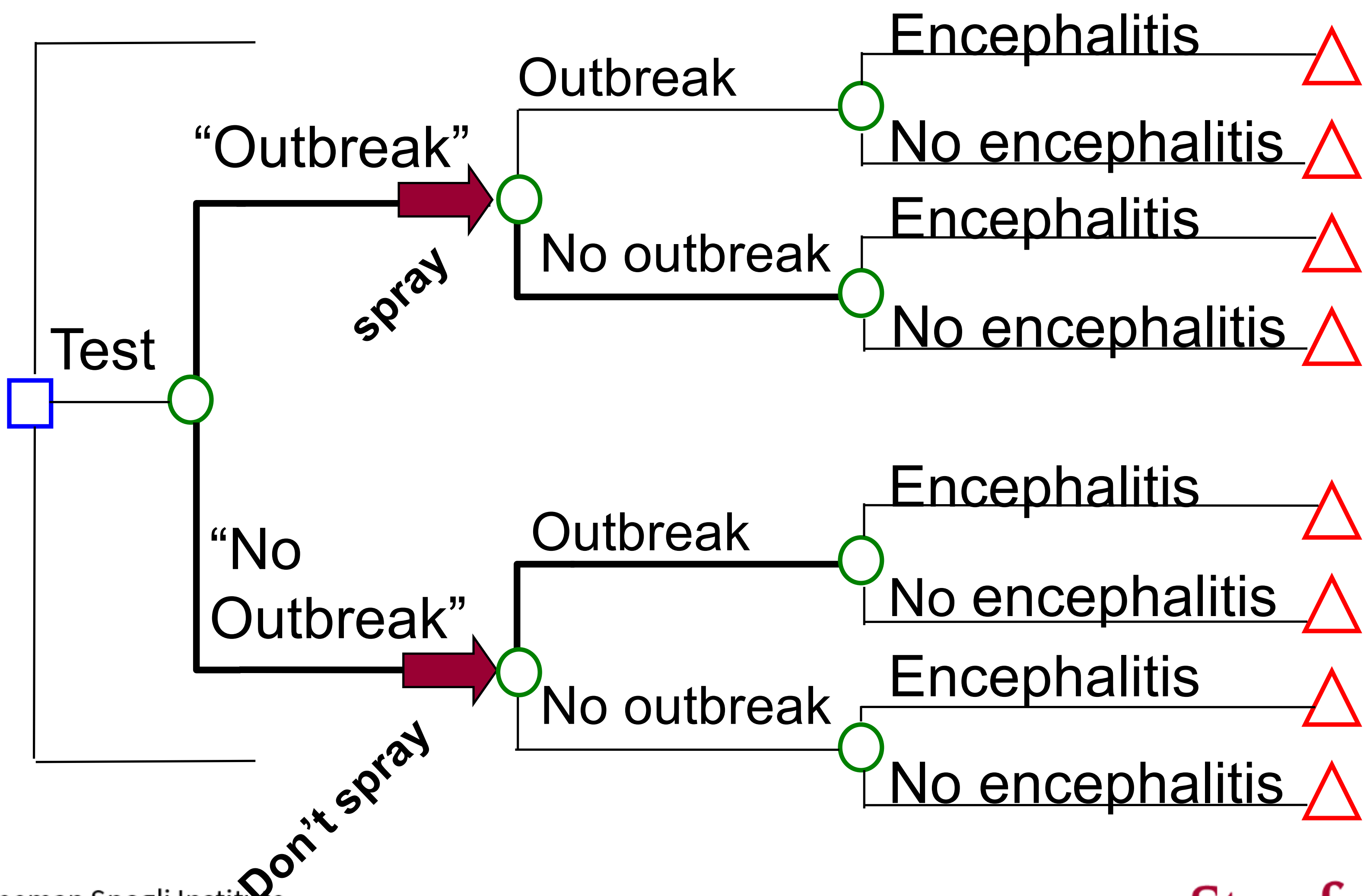
Expected Value of Information
(about a true state of nature)

- Information can theoretically be perfect, without risk, and free but it usually isn't!
  - Information is often **not perfect**
    - Sensitivity/specificity < 1
  - Getting information may involve **a "toll"**
    - Direct consequence of doing the test
    - Adverse effects due to the delay in treatment
    - Cost

Structure for Perfect Information



Structure for Imperfect Information



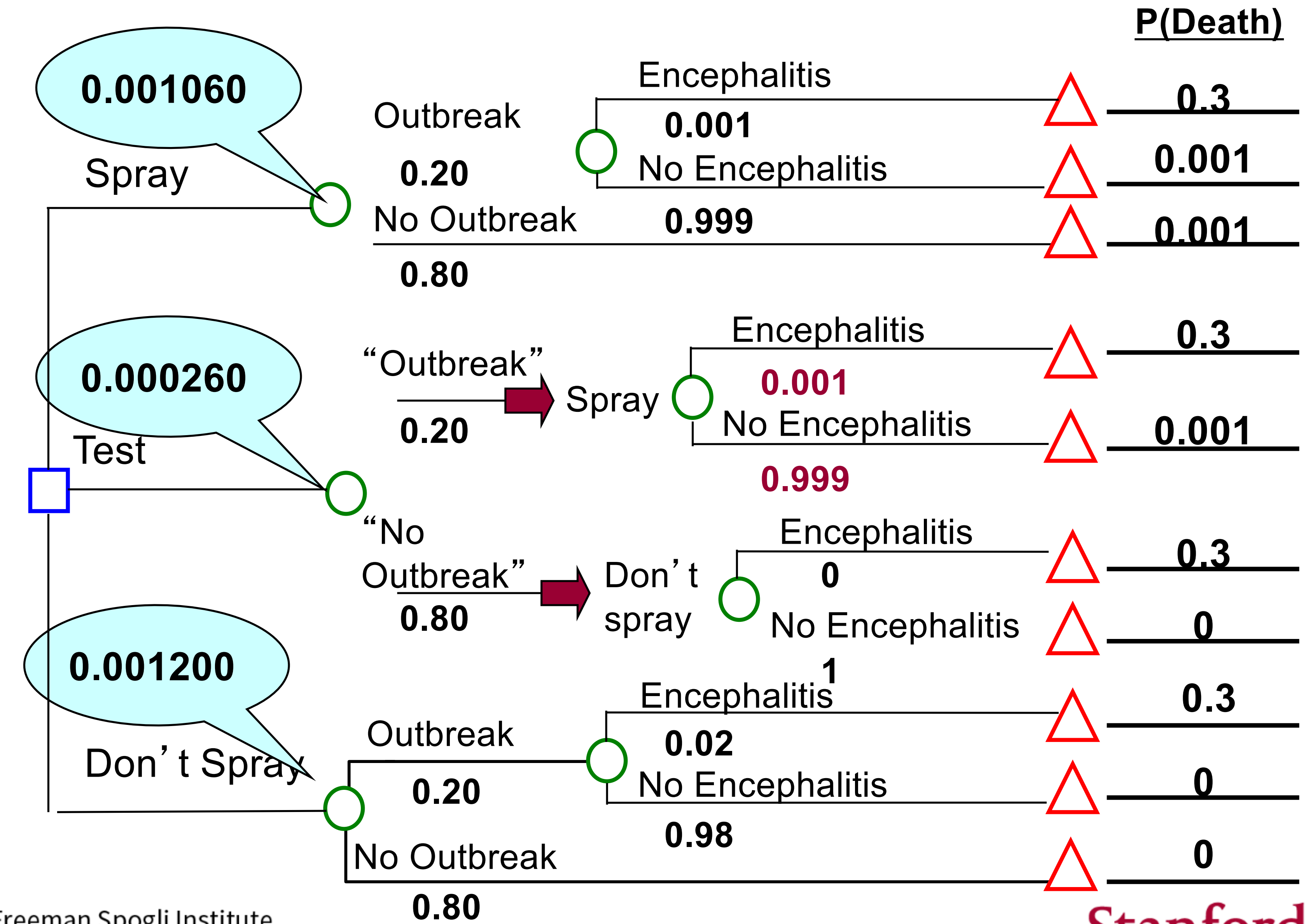
Expected Value of Perfect Information (EVPI)

- EVPI is the best you can do if the test is perfect and has no toll
- EVPI = difference between EV(without test) and EV(with perfect and toll-free test)
- Order of operation depends on outcome

EVPI (cont.)

- Order of operation
  - If lower values are better: EV(without test) – EV (with test)
  - If higher values are better: EV(with test) – EV(without test)
- EV(without test) = EV(Spray)
  - Best you can do without testing
- EV(perfect and toll-free test)?

Toll-free Test



Expected Value of Perfect Information (EVPI)

- EVPI is the best you can do if the test is perfect and has no toll:

E(# of deaths w/out test) –

E(# of deaths with toll-free test) =

106 – 26 = 80

80 deaths prevented with perfect information

Back to the Game Show (Session 1)

Choice between two games

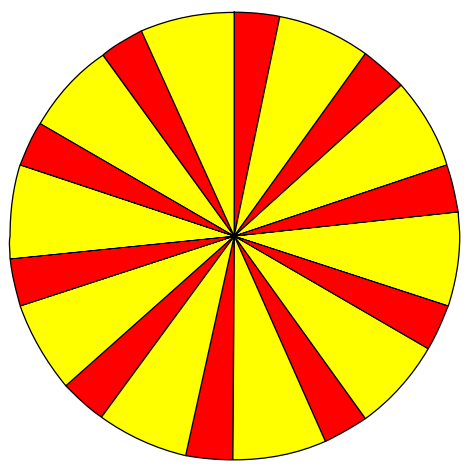
Game A

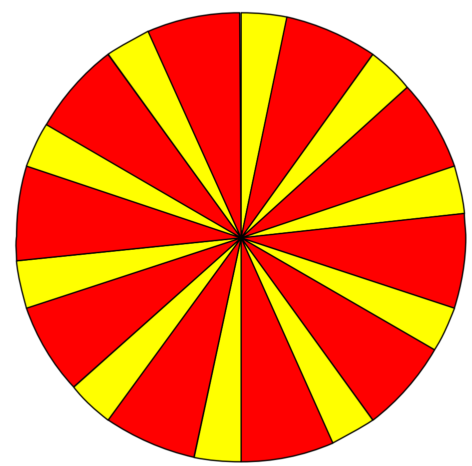
- Red=$400
- Gold=$600

Game B

- Red=$100
- Gold=$1000

E(A) = $500
E(B) = $550





Equal chance of: pRed= 1/3, 2/3

How much would you pay to get perfect information on which wheel it is (pRed)?

Cost-Effectiveness Analysis

- Cost-effectiveness analysis is decision analysis in the context of resource constraints
- Consider expected health benefits AND costs
    - Efficiency: incremental $ / incremental health benefit
- Common measure of health benefit
    - Quality-adjusted life-year (QALY)
    - Allows for comparison across different health domains (e.g., cavities vs. heart attacks)
- Decision must be made within a budget
- Cannot do all beneficial things, how to prioritize?

Cost-Effectiveness Analysis

- Relevant when alternative options have different costs and health consequences
- Costs are valued in monetary terms (e.g., CLP$)
- Benefits are valued in terms of outcomes (e.g., cases prevented or cured, lives saved, years of life gained, quality-adjusted life years gained)
- Results reported as an incremental cost-effectiveness ratio

Cost-Effectiveness Ratio

$$\frac{\text{Net increase in health care cost}}{\text{Net gain in health effect}}$$

A Special Case

$$\frac{\text{Net increase in health care cost}}{\text{Net gain in } \boxed{\text{quality-adjusted life years}}}$$

Cost-Utility Analysis

Two Types of Policy Decisions

Decision #1	Decision #2
- Malaria Deaths Prevention program	• Insecticide-treated nets • Spray houses • Drug prophylaxis
- Depression Screening program	
- Safe Motherhood program	
- Child Vaccination program	
- Cardiovascular Disease program	

Two Types of Policy Decisions

Decision #1	Decision #2
- Malaria Deaths Prevention program - Depression Screening program - Safe Motherhood program - Child Vaccination program - Cardiovascular Disease program	• Insecticide-treated nets • Spray houses • Drug prophylaxis
Allocative efficiency	Technical efficiency

Introduction to Resource Allocation

- How can we establish the relative priority of these various health programs that compete for limited resources?

Two Types of Policy Decisions

Decision #1	Decision #2

- Malaria Deaths Prevention program
- Depression Screening program
- Safe Motherhood program
- Child Vaccination program
- Cardiovascular Disease program

"Shopping Spree"

- Insecticide-treated nets
- Spray houses
- Drug prophylaxis

"Competing Choice"

Assumptions for Shopping Spree (1)

1. There are a number of available programs for which **net costs** and **net effectiveness** have been evaluated
2. There is a limited budget – total net cost of programs selected cannot exceed this amount
3. Objective is to maximize total net effectiveness of programs selected
4. Any combination of programs is feasible (but limited by budget constraint)

Assumptions for Shopping Spree (2)

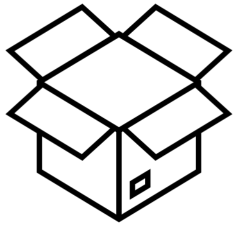
5. Net cost of any program does not depend on which other programs are also selected
6. Net effectiveness of any program does not depend upon which other programs are selected
7. All programs are divisible, with proportional costs and effectiveness

Shopping Spree Problem

Example

PROGRAM	COST ($)	EFFECT
A	27	30
B	30	20
C	56	70
D	20	40
E	30	50
F	50	75

Fund?



Budget $100

Which programs should be funded to maximize the total health benefit?

Divide Net Cost by Net Effect

PROGRAM	COST ($)	EFFECT	COST/ EFFECT
A	27	30	0.9
B	30	20	1.5
C	56	70	0.8
D	20	40	0.5
E	30	50	0.6
F	50	75	0.67

Order from lowest to highest ratio

PROGRAM	COST ($)	EFFECT	COST/ EFFECT
D	20	40	0.5
E	30	50	0.6
F	50	75	0.67
C	56	70	0.8
A	27	30	0.9
B	30	20	1.5

Accumulate costs & effects

Program	Cost ($)	Effect	Cost/ Effect	Cum. Cost	Cum. Effect
D	20	40	0.5	20	40
E	30	50	0.6	50	90
F	50	75	0.667	100	165
C	56	70	0.8	156	235
A	27	30	0.9	183	265
B	30	20	1.5	213	285

Spend the budget

Program	Cost ($)	Effect	Cost/ Effect	Cum. Cost	Cum. Effect
D	20	40	0.5	20	40
E	30	50	0.6	50	90
F	50	75	0.667	100	165
C	56	70	0.8	156	235
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Budget	Programs	Effect	Threshold
$100	**D,E,F**	**165**	**0.667**

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Budget	Programs	Effect	Threshold
$100	**D,E,F**	**165**	**0.667**
$183	**D,E,F,C,A**	**265**	**0.9**

Spend the budget

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Budget	Programs	Effect	Threshold
$100	D,E,F	165	0.667
$183	D,E,F,C,A	265	0.9
$150	D,E,F,(50/56)C	227.5	0.8

Solution for Shopping Spree Problem

1. Rule out programs with C > 0 and E < 0
2. Rule in programs with C < 0 and E > 0
3. Rank remaining programs in ascending order of cost-effectiveness ratios
4. Select programs from the rank list until budget is exhausted

Should Program H be Funded?

- Net Cost = $50
- Net Effect = 70
- Costs/Effect = 0.714

Should New Program H be Included?

Program	Cost ($)	Effect	Cost/ Effect	Cum. Cost	Cum. Effect
D	20	40	0.5	20	40
E	30	50	0.6	50	90
F	50	75	0.667	100	165
← H					
C	56	70	0.8		
A	27	30			
B	30	20			

Budget	Programs	Effect	Threshold	
$100	D,E,F	165	0.667	no
$150	D,E,F,(50/56)C	227.5	0.8	yes
$150	D,E,F,H	235	0.714	w/ H

Threshold Cost-Effectiveness Ratio

- Cost-effectiveness ratio of the last included program selected before budget exhausted
- Represents the standard against which programs that make claims against the budget can be judged
- As the budget rises (and we have more money available), what happens to the threshold cost-effectiveness ratio?

Competing Choice Problem: Assumptions

- Same as Shopping Spree, except…
- Some programs are mutually exclusive (i.e., if you select X_1, then you cannot select X_2, X_3, X_4, etc.)
- *Divisibility*: It is possible to offer different competing choice alternatives to different fractions of the target population (e.g., 50% X_1, 50% X_2)

Example 1: Budget $180

Program	Cost ($)	Effect	Cost/ Effect	Cum. Cost	Cum. Effect
D	20	40	0.5	20	40
E	30	50	0.6	50	90
F	50	75	0.67	100	165
C	56	70	0.8	156	235
A	27	30	0.9	183	265
B	30	20	1.5	213	285

Budget	Programs	Effect	Threshold
$180	**D,E,F,C,(24/27)A**	**261.7**	**0.9**

Which H Program should we fund, if any (Budget = $180)?

Program	Cost ($)	Effect
H1	60	80
H2	40	65
H3	55	70
H4	22	40
H5	45	60

Best we can do *without* Program H is D,E,F,C, and (24/27)A = 261.7. *Can we do better?*

Incremental Cost-Effectiveness Analysis

Program	Costs ($)	Effect
H1	60	80
H2	40	65
H3	55	70
H4	22	40
~~H5~~	~~45~~	~~60~~

H5 costs more and is less effective than H2 (dominated)!

Order in terms of increasing costs and effectiveness

Program	Cost ($)	Effect	*Avg C/E*	Inc. Costs	Inc. Eff.	Inc. C/E
H4	22	40	0.55	--	--	--
H2	40	65	0.62	18	25	0.72
H3	55	70	0.79	15	5	3.0
H1	60	80	0.75	5	10	0.5

Are incremental CE ratios increasing?

Program	Cost ($)	Effect	*Avg C/E*	Inc. Costs	Inc. Eff.	Inc. C/E
H4	22	40	0.55	--	--	--
H2	40	65	0.62	18	25	0.72
~~H3~~	~~55~~	~~70~~	~~0.79~~	~~15~~	~~5~~	~~3.0~~
H1	60	80	0.75	5	10	0.5

H3 eliminated by extended (or weak) dominance.

Recalculate ICERs

Program	Cost ($)	Effect	*Avg C/E*	Inc. Costs	Inc. Eff.	Inc. C/E
H4	22	40	0.55			**--**
H2	40	65	0.62	18	25	**0.72**
H1	60	80	0.75	20	15	**1.33**

These are the ratios to compare to the threshold

Recalculate ICERs

Program	Cost ($)	Effect	*Avg C/E*	Inc. Costs	Inc. Eff.	Inc. C/E
H4	22	40	0.55			**--**
H2	40	65	0.615	18	25	**0.72**
H1	60	80	0.75	20	15	**1.33**

These ratios are meaningless!

Back to the Example

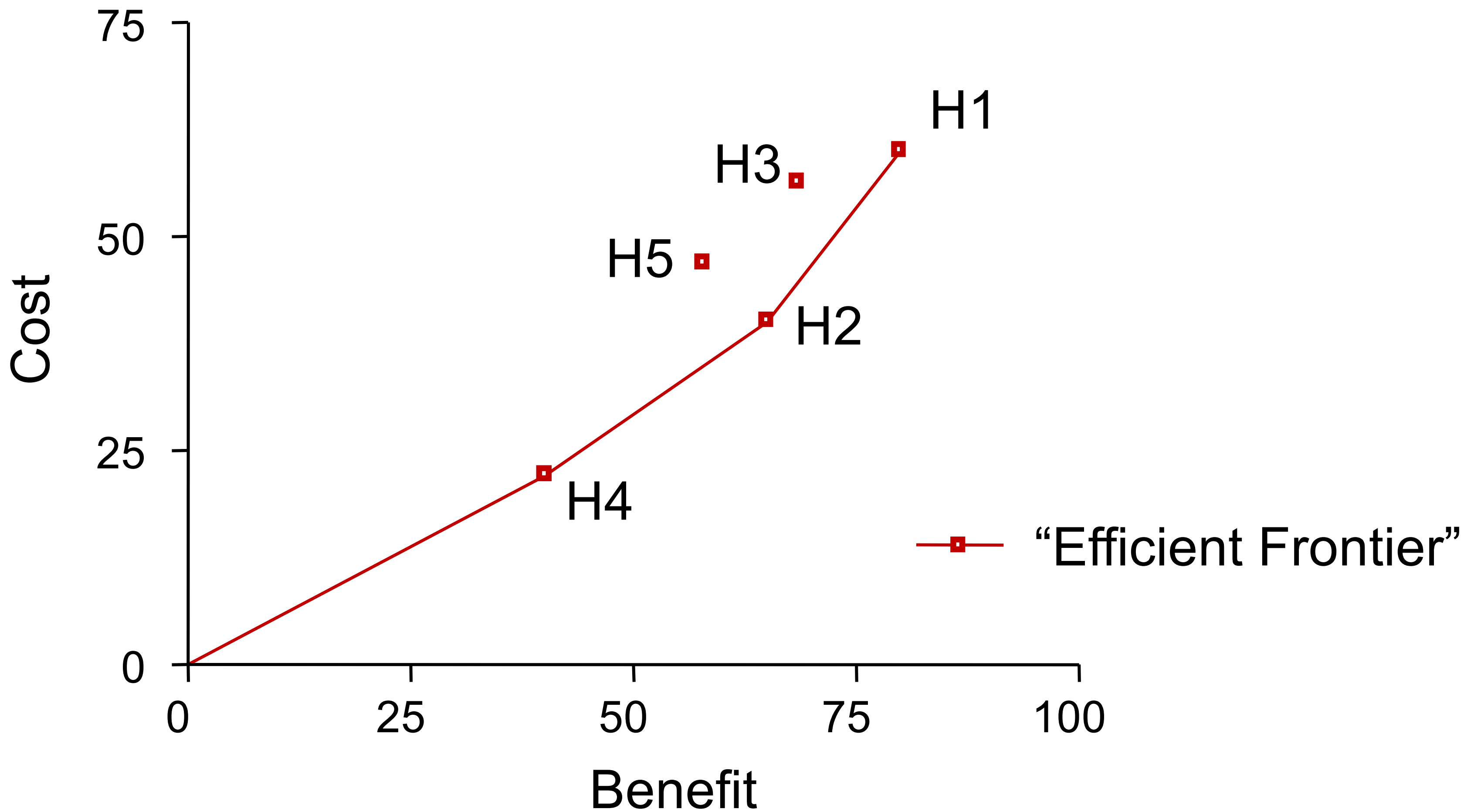
Program	Cost ($)	Effect	C/E	Cum. Cost	Cum. Effect
D	20	40	0.5	20	40
E	30	50	0.6	50	90
F	50	75	0.67	100	165
H2	40	65	0.72	140	230
C	56	70	0.8	196	300
A	27	30	0.9		
B	30	20	1.5		

Maximum benefit is obtained by implementing D,E,F, H2,(40/56)C **= 280**.

The Right Way

Program	Cost ($)	Effect	C/E	Cum. Cost	Cum. Effect
D	20	40	0.5	20	40
H4	22	40	0.55	42	80
E	30	50	0.6	72	130
F	50	75	0.667	122	205
H2→H4	18	25	0.72	140	230
C	56	70	0.8	196	300
A	27	30	0.9	223	330
H1→H2	20	15	1.33	243	345
B	30	20	1.5	273	365

Results of Competing Choice (1)



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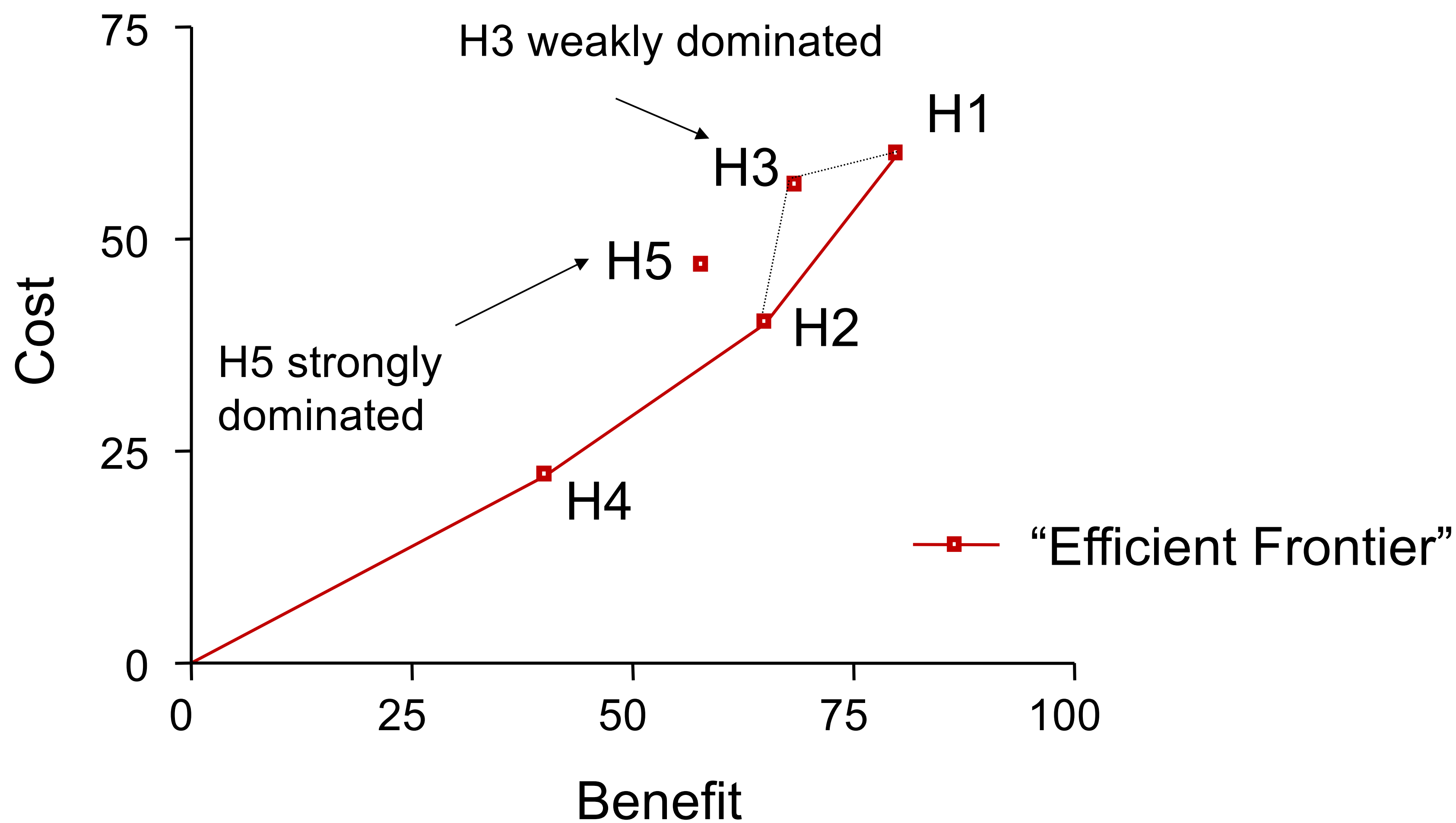
Results of Competing Choice (2)



Competing Choice Solution

- Arrange the competing programs in increasing order of cost
- Exclude the strongly dominated options
- Calculate incremental C/E for remaining options
- Exclude the weakly dominated options
- Recalculate incremental C/E for remaining options
- Repeat until remaining options are in increasing order of C/E

Net (Health or Monetary) Benefit

- Determine the threshold CE ratio (λ)
- For each competing option, compute the net health benefit (NHB):

$$\text{NHB} = \text{Benefit} - \text{Cost} * (1/\lambda)$$

- Or, compute the net monetary benefit (NMB):

$$\text{NMB} = \text{Benefit} * \lambda - \text{Cost}$$

- Select the option with greatest NHB or NMB

NHB Methods

Budget = $180 (Threshold = 0.9)

Program	Cost ($)	Effect	NHB
H1	60	80	13.3
H2	40	65	**20.6**
H3	55	70	8.9
H4	22	40	15.6
H5	45	60	10.0

Net Health or Monetary Benefit

- For a given C/E threshold, the competing choice alternative with the greatest net health benefit (NHB, or NMB) is the most cost-effective option *at that budget constraint*.

- The procedure of comparing NHB at a fixed C/E threshold is equivalent to applying the rule of selecting the *largest* competing alternative whose incremental C/E ratio is below the C/E threshold.

CEA of Testing

- Disease Y is a serious disease for which prompt treatment can greatly reduce mortality. Without treatment, one-year survival with the disease is 80%. With treatment, one-year survival is 90%. Patients who survive the first year are cured and have a normal life span. Treatment costs $20,000.
- A genetic abnormality is associated with Disease Y. About one of every 100 patients who have this abnormal gene have Disease Y; the others are normal. Of the patients without the disease, but who are nonetheless treated, 1% will die within one year as a result of the risks of treatment.

Two Tests for Disease Y

- Two diagnostic tests are available. Test 1 costs only $20, has a sensitivity of 90% and a specificity of 95%. Test 2 costs $1000, and can confirm with certainty the presence or absence of disease.
- The analysis pertains to individuals with the identified genetic abnormality and in whom, therefore, Disease Y is suspected.

Testing Strategies

- Estimate the benefits and cost-effectiveness of “screening” with Test 1, assuming Test 2 is not available to confirm the diagnosis
- Estimate the clinical benefits and cost-effectiveness of using the more accurate Test 2
  - Note: Test 2 can be used as a confirmatory test in patients who “screen” positive with Test 1, or can replace Test 1
- Express results in terms of cost-per-life year saved

Outcomes

Outcome	One-Year Survival
Y+, no treatment	0.80
Y+, treatment	0.90
Y-, no treatment	1.00
Y-, treatment	0.99

Assume that the discounted life expectancy is 10 yrs among survivors.

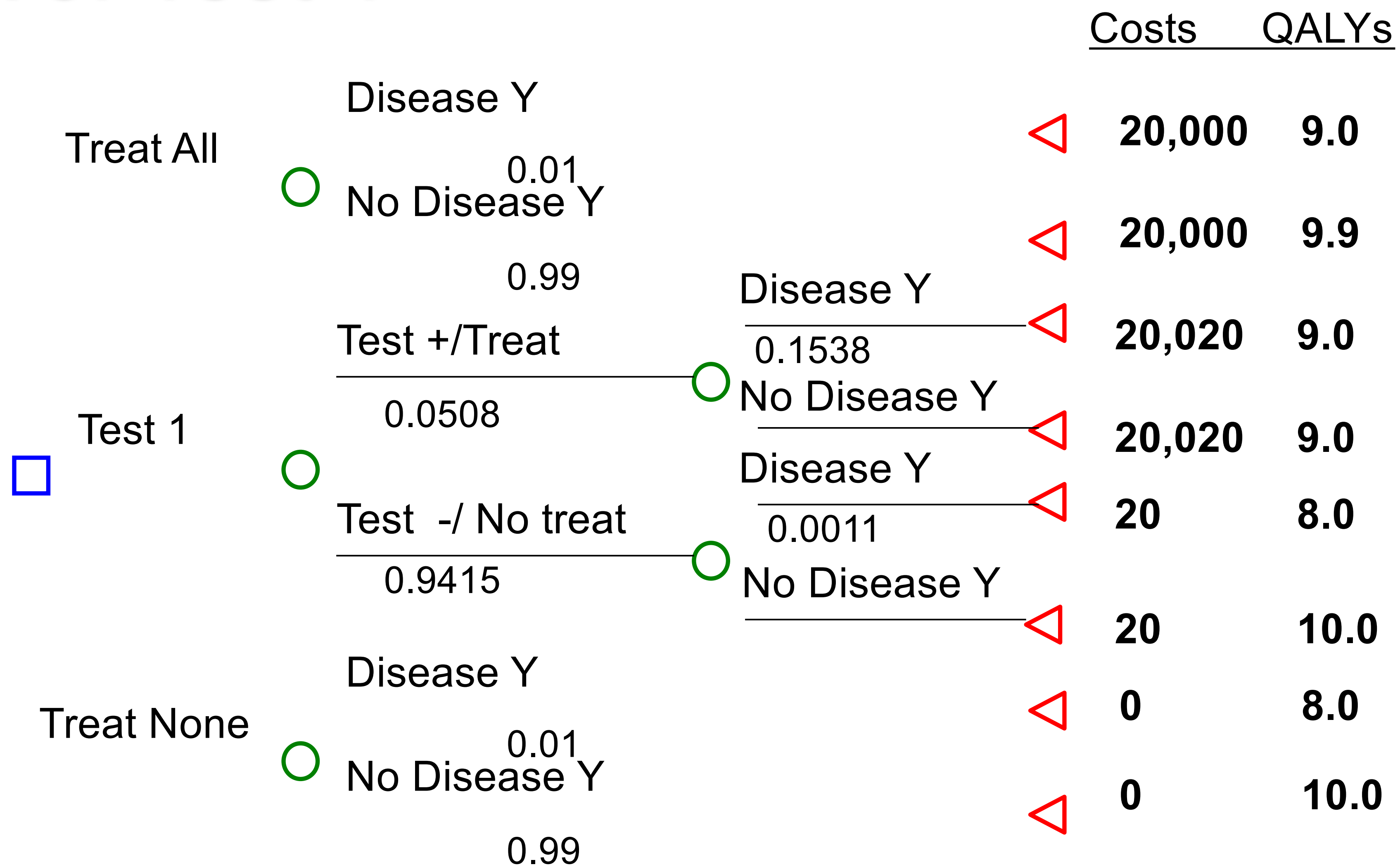
Other Information

Variable		*Cost*
No treatment		$0
Treatment		$20,000
Test 1		$20
Test 2		$1,000

Test	*Sensitivity*	*Specificity*
Test 1	0.90	0.95
Test 2	1.0	1.0

Prevalence = 0.01

CEA of Test 1

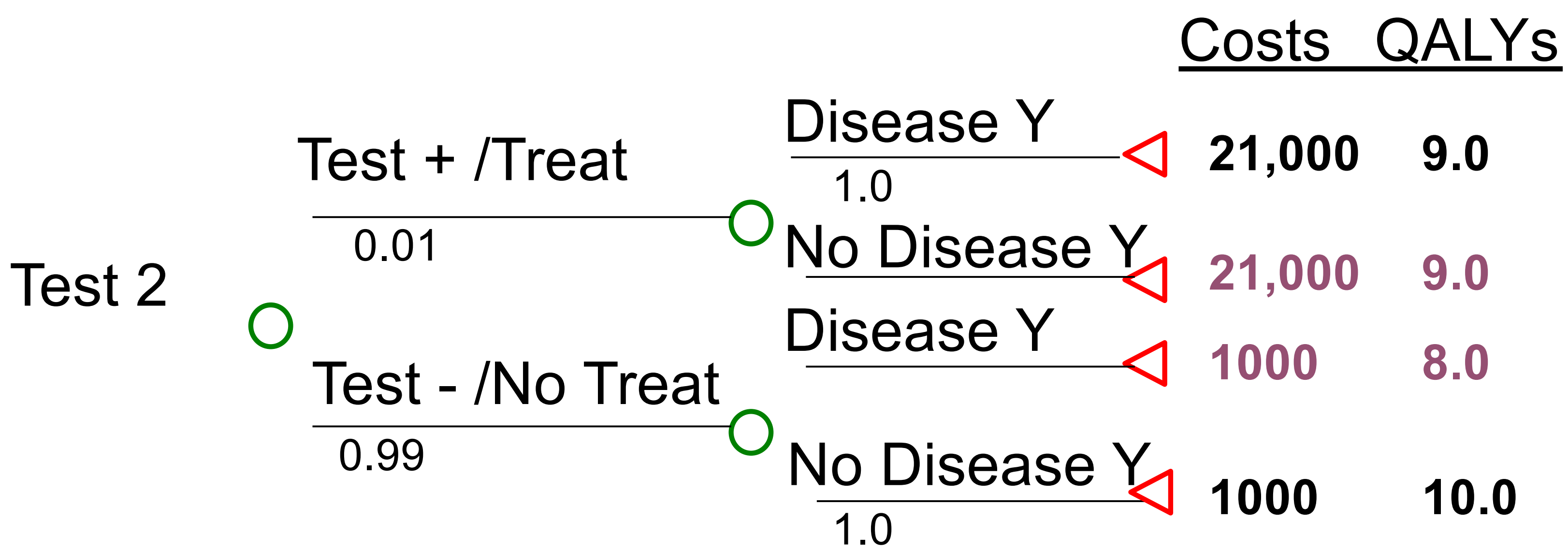

Costs QALYs
Treat All
Disease Y
0.01
No Disease Y
0.99
Test 1
Test +/Treat
0.0508
Disease Y
0.1538
No Disease Y
Test -/ No treat
0.9415
Disease Y
0.0011
No Disease Y
Treat None
Disease Y
0.01
No Disease Y
0.99
20,000 9.0
20,000 9.9
20,020 9.0
20,020 9.0
20 8.0
20 10.0
0 8.0
0 10.0

Results for Test 1

What is the cost-effectiveness of screening with Test 1, assuming that Test 2 is not available?

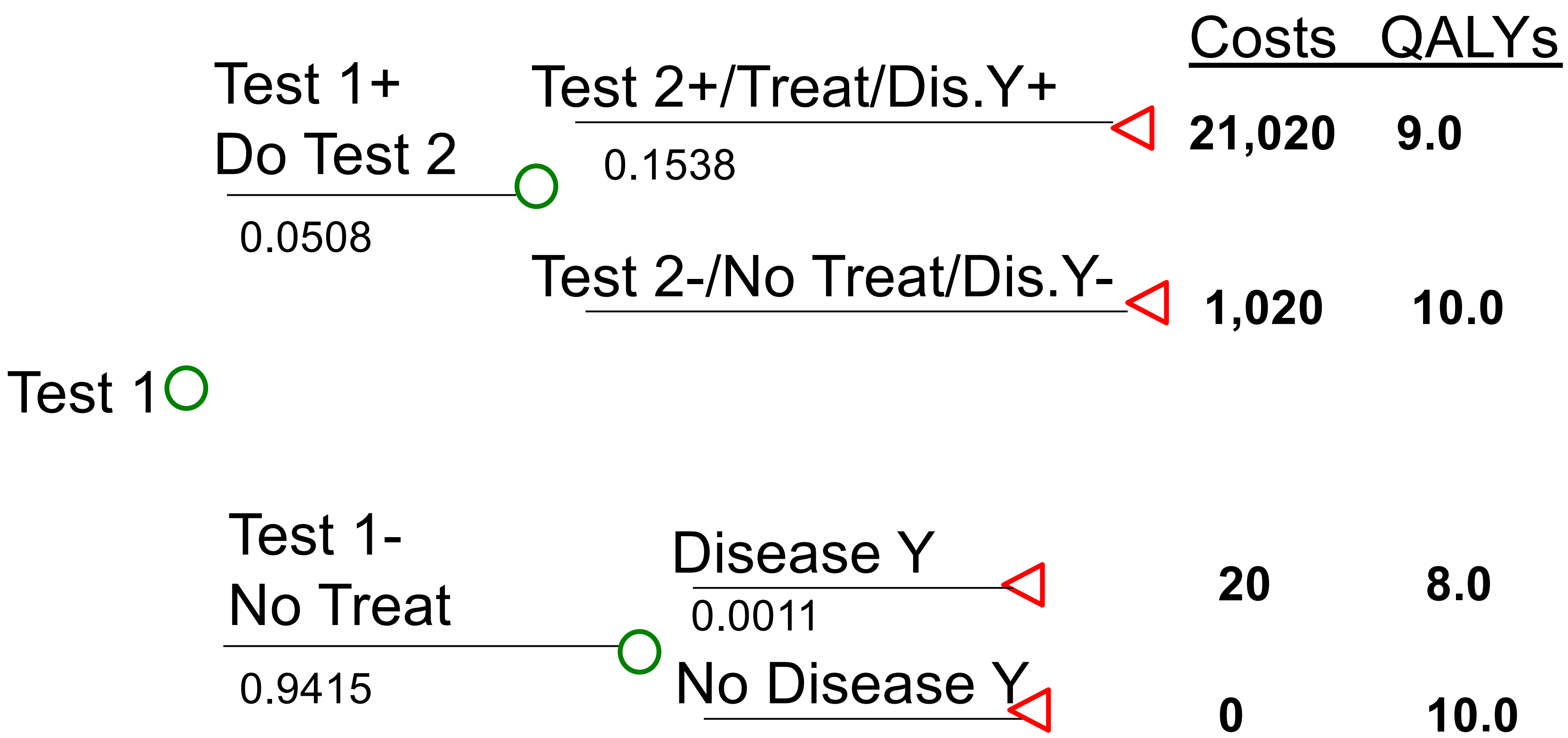
Strategy	Cost ($)	QALE	ΔC	ΔE	ΔC/ΔE
No Treat	0	9.980			
Test 1	1190	9.984	1190	0.004	294K
Treat	20,000	9.891	18,810	-0.093	Dom

Test 2 Strategy



Do Test 2, if positive, treat; if negative, no treat

Test 1/2 Strategy



Do Test 1, if positive, do Test 2 strategy; if negative, no treat

Practice Problem-CEA Results

Incremental Cost-Effectiveness Analysis

Strategy	Cost ($)	QALE	ΔC	ΔE	ΔC/ΔE
No Treat	0	9.980			
Test 1/2	259	9.989	259	0.009	28,700
~~Test 1~~	~~1,190~~	~~9.984~~	~~*Dominated*~~		
Test 2	1,200	9.990	942	0.001	941,500
~~Treat~~	~~20,000~~	~~9.891~~	~~*Dominated*~~		

*cost per LYS

Thank you!

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