LIFE TABLE AND SURVIVAL ANALYSIS

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Definition

- A life table comprises of a set of values showing how a group of infants born on the same day and living under similar conditions would gradually die out. In other word a life table summarise the mortality or longevity of any cohort.

Background

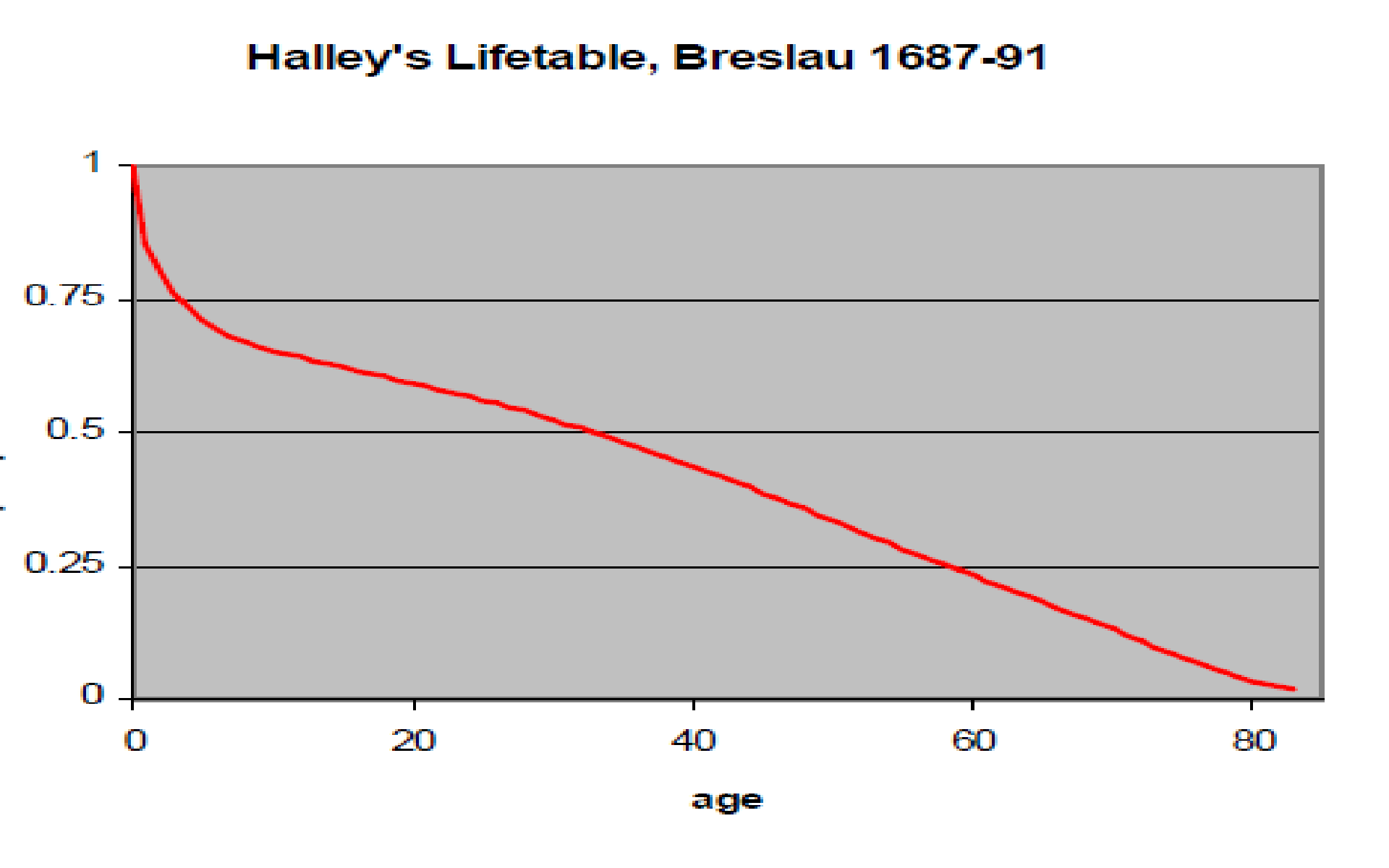
- **The concept of life table was first given by John Graunt in London in 1662 in a book entitled *Natural and Political Observations Made upon the Bills of Mortality.***
- **At about the same time, Caspar Neumann, living in Breslau, was collecting data about the number of birth, deaths and other vital statistics in his city.**

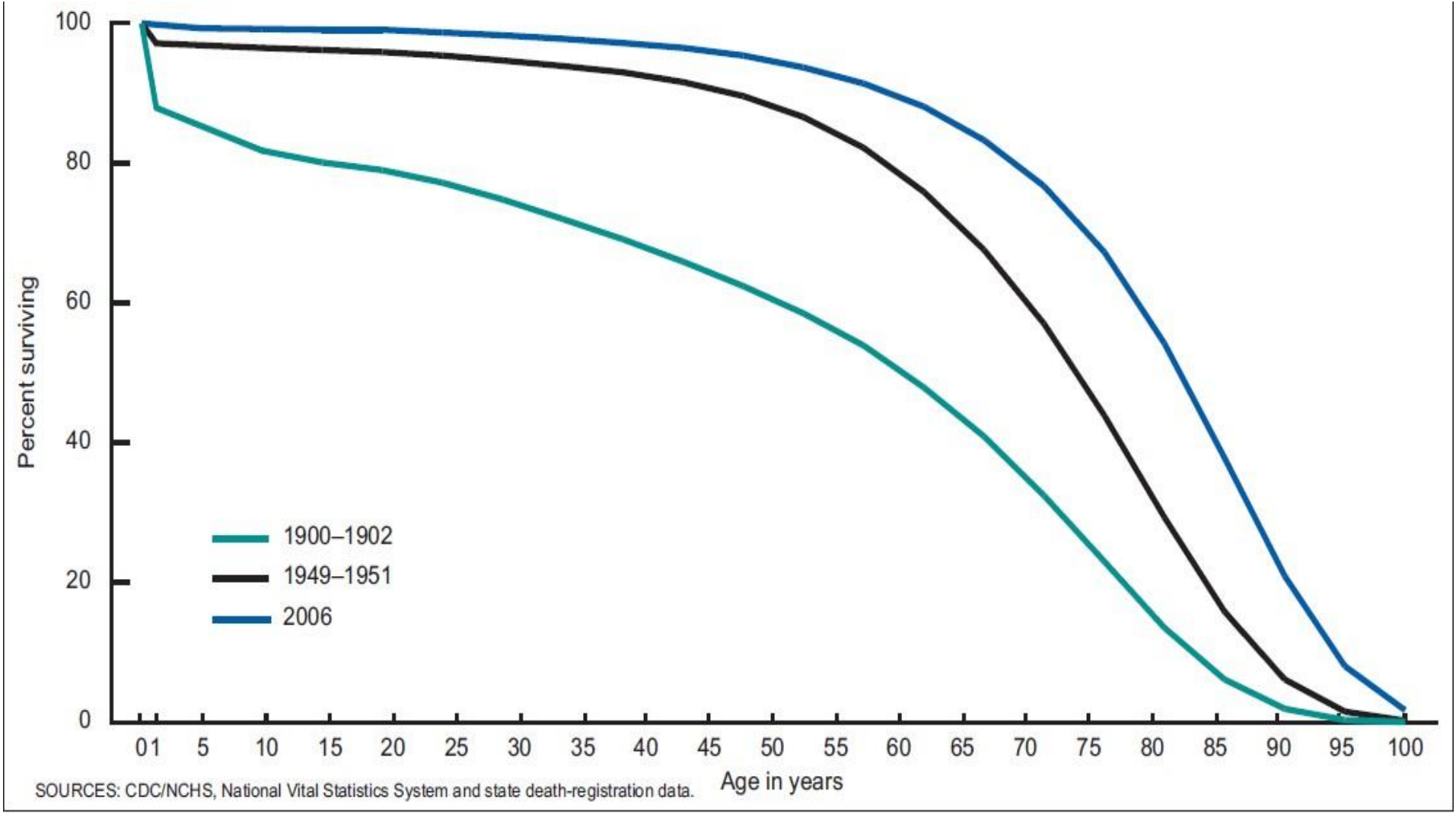
- **Just after death of Caspar Neumann, Halley got hold of the data, analyzed them and in 1693 published his conclusions in the Philosophical Transactions of the Royal Society.**
- **Edmond Halley -The first person to show how to construct the life table.**
- **Halley was a British astronomer, mathematician, meteorologist who is best known for computing the orbit of Halley's comet.**

- **Life table tells us how long people live on an average.**
- **It converts a cross sectional information into a longitudinal cohort information.**

Halley's life table of Breslau city

Age. Curt.	Per-sons.	Age. Curt.	Per-sons	Age. Curt.	Per-sons	Age. Curt.	Per-sons	Age. Curt.	Per-sons	Age. Curt.	Per-sons
1	1000	8	680	15	628	22	586	29	539	36	481
2	855	9	670	16	622	23	579	30	531	37	472
3	798	10	661	17	616	24	573	31	523	38	463
4	760	11	653	18	610	25	567	32	515	39	454
5	732	12	646	19	604	26	560	33	507	40	445
6	710	13	640	20	598	27	553	34	499	41	436
7	692	14	634	21	592	28	546	35	490	42	427
Age. Curt	Per-sons.	Age. Curt.	Per-sons	Age. Curt.	Per-sons	Age Curt	Per-sons	Age. Curt.	Per-sons	Age. Curt.	Per-sons
43	417	50	346	57	272	64	202	71	131	78	58
44	407	51	335	58	262	65	192	72	120	79	49
45	397	52	324	59	252	66	182	73	109	80	41
46	387	53	313	60	242	67	172	74	98	81	34
47	377	54	302	61	232	68	162	75	88	82	28
48	367	55	292	62	222	69	152	76	78	83	23
49	357	56	282	63	212	70	142	77	68	84	20


Halley's Lifetable, Breslau 1687-91
1
0.75
0.5
0.25
0
0
20
40
60
80
age



United States, 1949–1951 and 2006

In short

- **Life table methodology constructs a life experience for a fictional cohort subjected to current mortality rates as it progresses through life, as if the current rates do not change.**

Assumptions of Life Table

- A hypothetical cohort of life table usually comprises of 1,000 or 10,000 or 1,00,000 births.
- Deaths equally distributed throughout the year.
- Cohort of people diminish gradually by death only.
- Cohort is closed to the in-migration and out-migration.
- Death rate is related to a pre-determined age specific death rate.
- No change in death rates overtime.
- Life tables are generally constructed separately for males and females.

Construction of a life table

- To construct a life table, two things are required:

I. Population living at all individual ages in a selected year.

II. Number of deaths that occurred in these ages during the selected year.

Procedures

- Age (x) and Number started life (lx)
- Determine the number of deaths (dx)in each age category.
- Determine probability of dying (qx) and probability of surviving (px) at each age.
- Calculate No. of person -years lived (Lx) at each age.
- Construct a column called (Tx), the sum of all the (Lx) up to that age category.
- Calculate expectation of future life for each age category- ex = Tx / lx
- ex is expressed in the number additional life expected.

Example

Age (x)		No. started life (lx)	
X0	0	l0	50
X1	1	l1	36
X2	2	l2	21
X3	3	l3	12
X4	4	l4	6
X5	5	l5	2
X6	6	l6	0

Age	No. started life	No. died	Probability of dying	Probability of surviving	No. of person - years lived	Total person-years lived	Expectation of life
x	lx	dx= lx-(lx+1)	qx= dx/lx	px = (1-qx)	Lx = lx+(lx+1)/2	∑ Lx	e°_{x}= Tx/lx
0	50	50-36 =14	14/50 =0.28	0.72	(50+36)/2 =43	102	102/50 =2.04
1	36	36-21 =15	15/36 =0.42	0.58	(36+21)/2 =28.5	59	59/36 =1.64
2	21	9	0.43	0.57	16.5	30.5	1.45
3	12	6	0.50	0.50	9	14	1.17
4	6	4	0.67	0.33	4	5	0.83
5	2	2	1	0	1	1	0.5
6	0	-	-	-	-	-	-

Types of Life table

- **1. Current v/s Cohort.**
- **2. Complete v/s Abridged.**
- **3. Single decremental v/s Multiple decremental tables.**
- **4. Incremental –Decremental life table (Multi state life table)**

- ***The cohort life table (Generation)*** **presents the mortality experience of a particular birth cohort.**
- **All persons born in a year, from the moment of birth through consecutive ages in successive calendar years.**
- **The cohort life table reflects the mortality experience of an actual cohort from birth.**

- ***Current (period life table)***

- **Based on the mortality experience of the community for a short period of time such as one year/two year…**

- ***A complete life table*** **contains data for every year of age. Here information is given for every year of age from birth to the last age**
- ***An abridged life table*** **typically contains data by 5-or 10-year age intervals .**
- **A separate group is made for age group 0-1 years.**
- **In India a 5 year interval is selected. Here information is given for age intervals such as x to x+5 years.**

Applications of Life table

- **To find the number of survivors out of 1,000 or 10,000 at any age say,**

a. **At the age of 5, to find number of children likely to enter primary school.**

b. **At the age of 15, to find number of women entering fertile period.**

c. **At age of 18, to find number of persons become eligible for voting.**

- **To estimate the number likely to die after joining service till retirement, helping in budgeting for payment towards risk or pension.**
- **To find expectation of life or longevity of life at birth or any other age.**
- **To compare mortality of two places, periods, professions or groups.**
- **Helps to project population estimates by age & sex.**

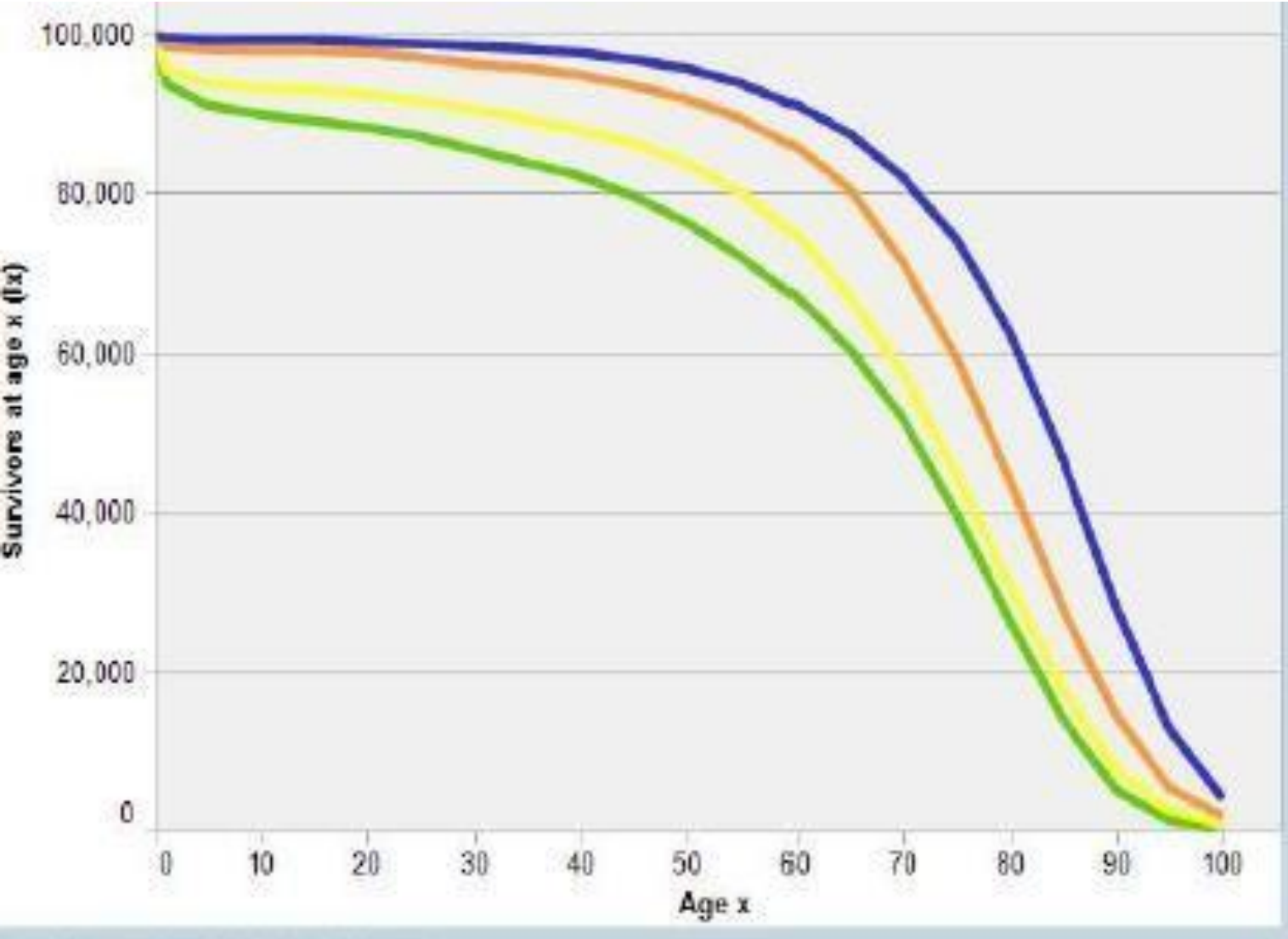
- **To estimate the cause of specific death rates, male and female death rates, etc**
- **By constructing a life table based on the age at marriage, marriage patterns and changes in them can be estimated.**
- **Used for formulating family planning programmes relating to infant mortality, maternal deaths, health programmes, etc.**

- **To find survival rate after treatment in chronic disease like tuberculosis, cancer or after cardiac surgery by modified life table.**

- **Calculate failure rate of contraceptive.**

- **life table methods used to study birth control effectiveness, (alternative to the Pearl Index)**
- **A decrement table calculates a separate effectiveness rate for each month of the study, as well as for a standard period of time (usually 12 months).**
- **Use of life table methods eliminates time-related biases (i.e. the most fertile couples getting pregnant and dropping out of the study early, and couples becoming more skilled at using the method as time goes on), and in this way is superior to the Pearl Index.**

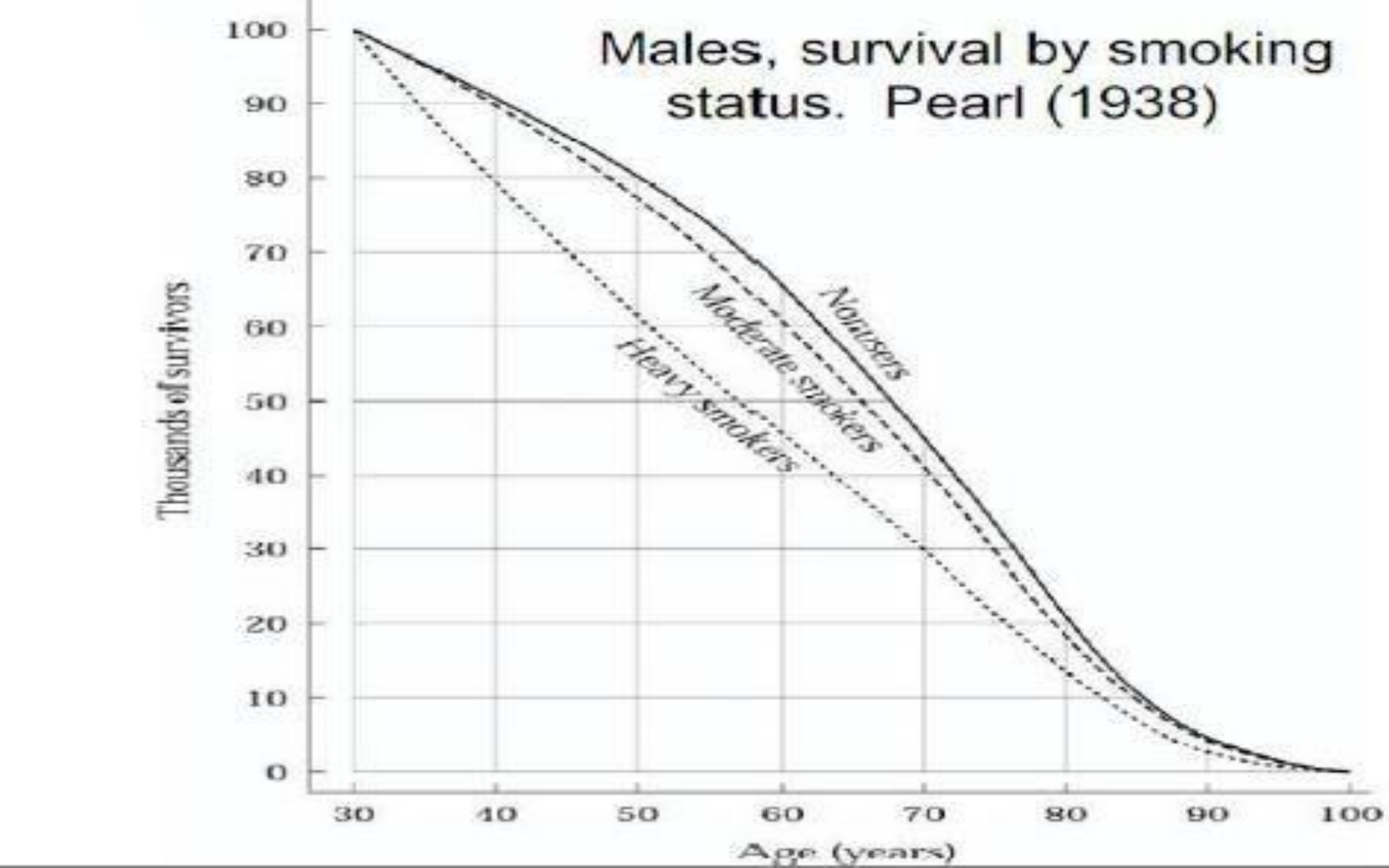
- **Life table shows the probability of a person at a certain age dying before their next birthday.**
- **Mathematically and statistically based actuarial life tables assist insurance companies by showing event probabilities, such as death, sickness, and disability.**
- **An actuarial life table can also include factors to differentiate variable risks such as smoking, occupation, socio-economic status, etc**



The graph plots the number of survivors across ages x (lx) out of a hypothetical 100 000 births given the age-specific death rates of 2011 for each income group.

lx is a component of a life table

Source: WHO mortality statistics, 2013


Males, survival by smoking status. Pearl (1938)
Thousands of survivors
100
90
80
70
60
50
40
30
20
10
0
30
40
50
60
70
80
90
100
Age (years)
Nonusers
Moderate smokers
Heavy smokers

Kaplan Meier Method

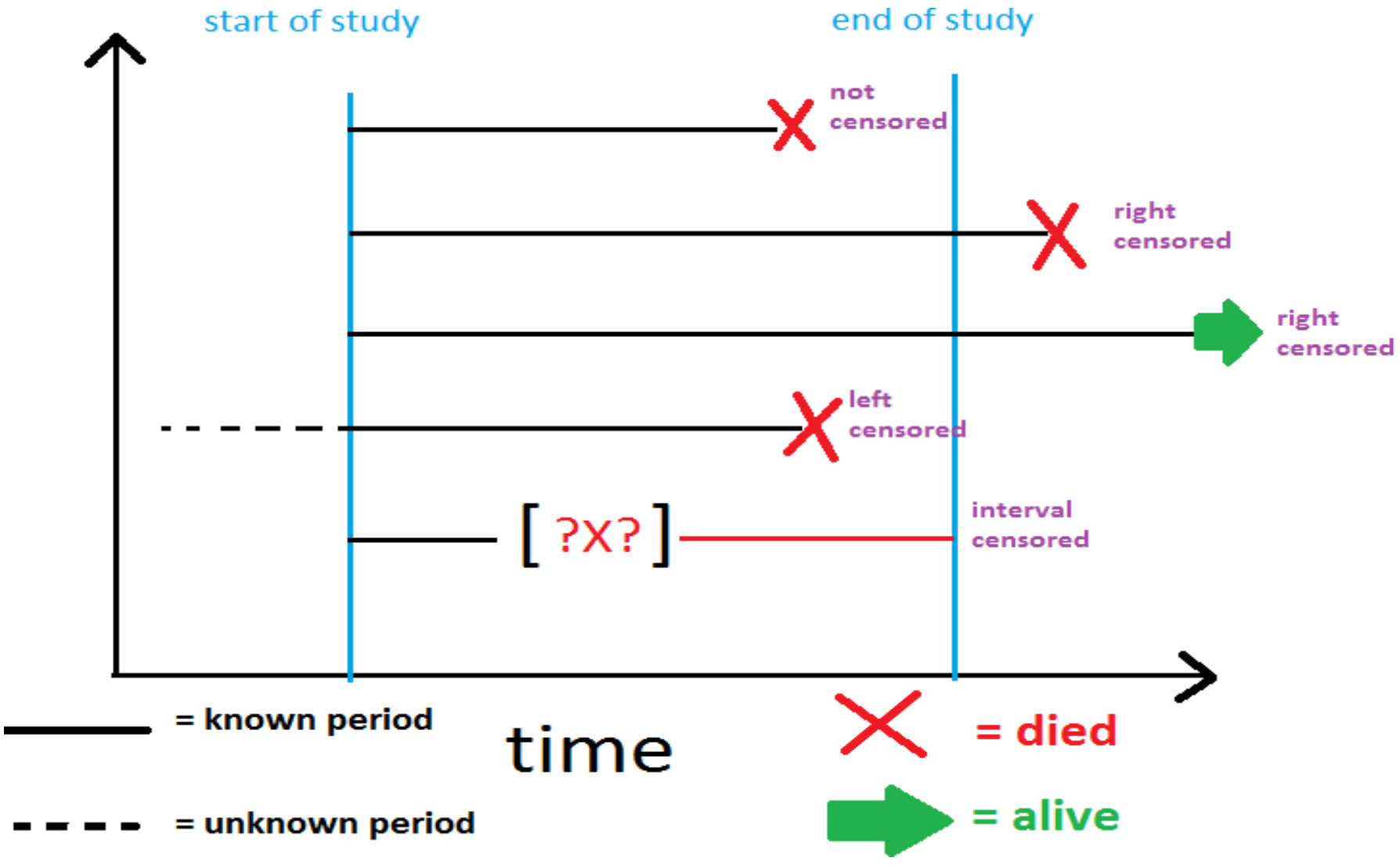
- **Similar to life table analysis except time since entry in the study is not divided into intervals for analysis.**
- **Survival is estimated each time a patient has an event**
- **It gives exact survival times in comparison to life table because it does not group survival time into intervals.**

Assumptions

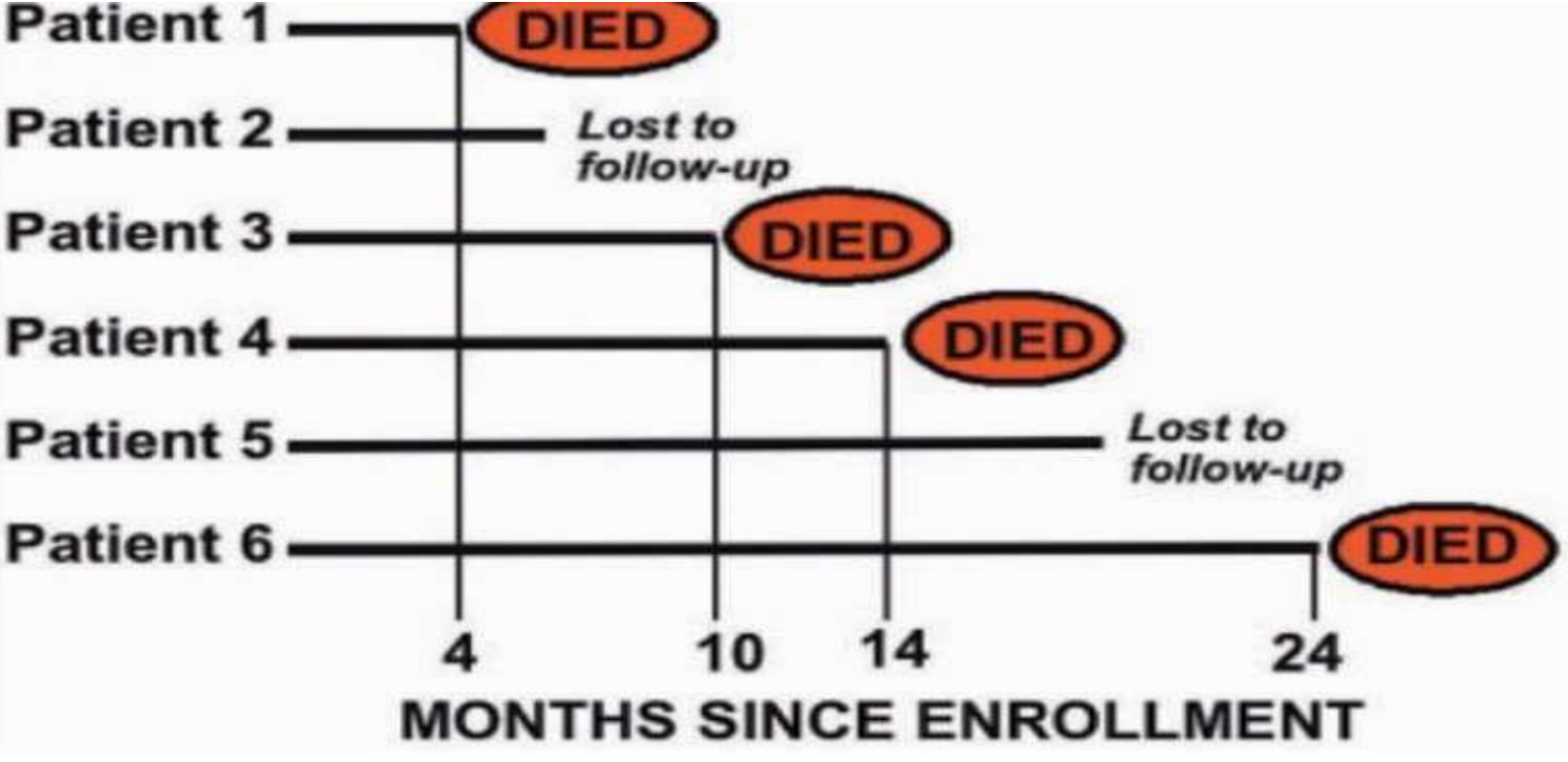
- **Assume that at any time patients who are censored have the same survival prospects as those who continue to be followed.**
- **Assume that the survival probabilities are same for subjects recruited early and late in the study.**
- **Assume that the event happens at the time specified**

Subjects are said to be censored

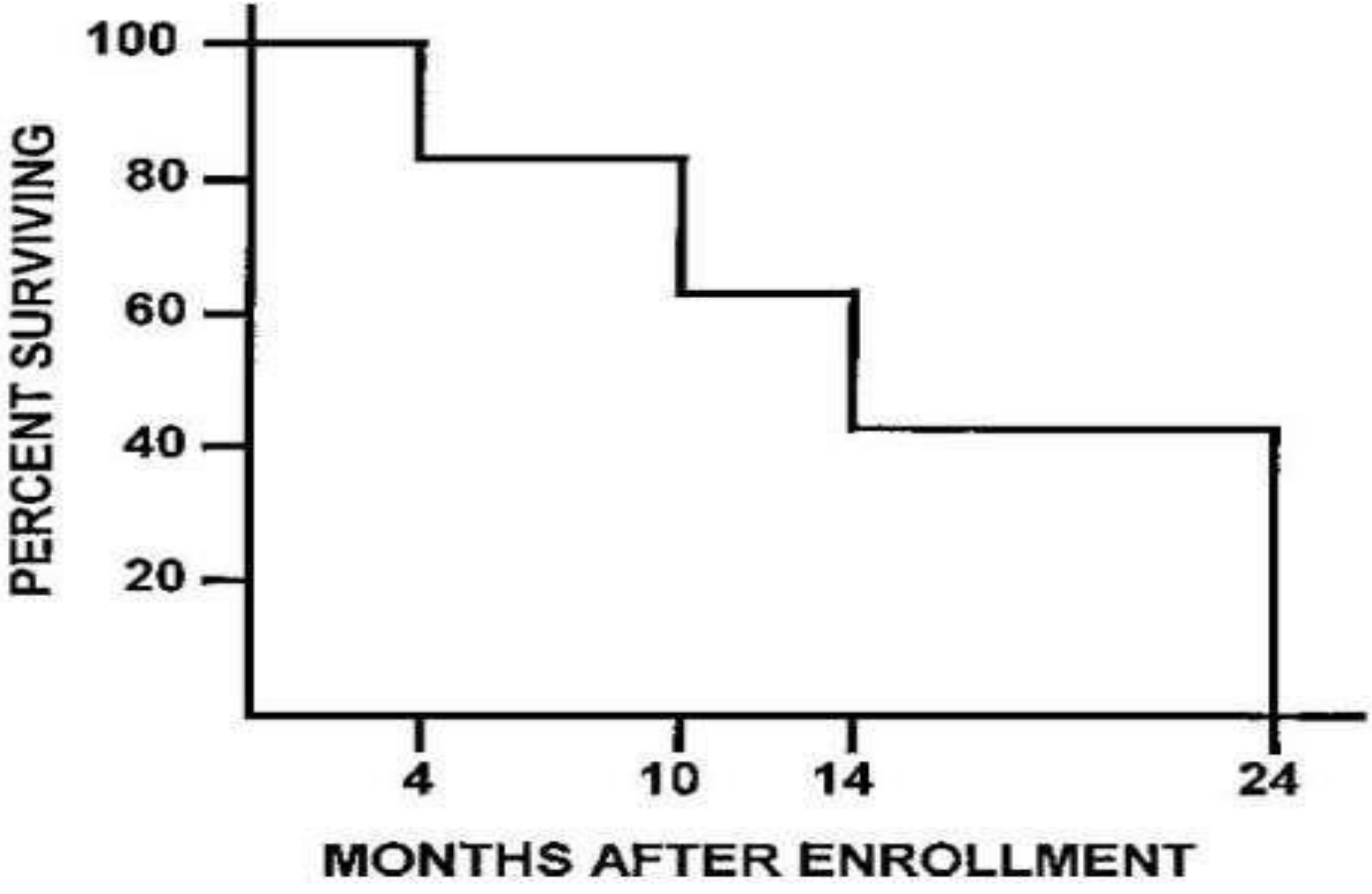
- **If they are lost to follow up/Drop out of the study,**
- **If the study ends before they die or have an outcome of interest.**
- **They are counted as alive or disease-free for the time they were enrolled in the study.**
- **In simple words, some important information required to make a calculation is not available to us. i.e. censored.**


start of study
end of study
not censored
right censored
right censored
left censored
[?X?]
interval censored
= known period
= unknown period
time
= died
= alive

Example



Hypothetical example of a study of six patients analyzed by the Kaplan-Meier method.



Kaplan-Meier plot of the survival study

Limitations of Life Table

- **Hypothetical measure, has potential to be misunderstood by general public/media.**
- **It does not say about quality of life; for example, how many years are lived with disability before dying.**
- **It's based on assumption that the cohort is closed for migration in or out. Hence the change in the cohort is only due to death.**

Survival Analysis

OUTLINE

- What is Survival Analysis?
- Censored Data
- Kaplan-Meier Estimator
- Log-Rank Test
- Cox Regression Model

WHAT IS SURVIVAL ANALYSIS?

- Branch of statistics that focuses on time-to-event data and their analysis.
- Survival data deals with time until occurrence of any well-defined event.
- The outcome variable examined is the survival time
- Special because it can incorporate information about censored data into analysis.

OBJECTIVES OF SURVIVAL ANALYSIS?

- Estimate probability that an individual surpasses some time-to-event for a group of individuals.
  - Ex) probability of surviving longer than two months until second heart attack for a group of MI patients.
- Compare time-to-event between two or more groups.
  - Ex) Treatment vs placebo patients for a randomized controlled trial.
- Assess the relationship of covariates to time-to-event.
  - Ex) Does weight, BP, sugar, height influence the survival time for a group of patients?

SITUATIONS WHEN WE CAN USE SURVIVAL ANALYSIS

- We can use survival analysis when you wish to analyze survival times or “time-to-event” times
- “Time-to-Event” include:
  - Time to death
  - Time until response to a treatment
  - Time until relapse of a disease
  - Time until cancellation of service
  - Time until resumption of smoking by someone who had quit
  - Time until certain percentage of weight loss

MORE EXAMPLES

- Suppose you wish to analyze the time it takes for a student to complete a series of classes.
  - Response /Status Variable: Time it takes to complete, status
  - Predictor Variables: Age, Gender, Race, GPA

- Suppose you are interested in comparing the time until you lose 10% body weight on one of two exercise programs.
  - Response/Status Variables: Time it Takes, Status
  - Predictor Variables: Age, Gender, Starting Weight, BP, BMI, Exercise Program

DATA

- Survival data can be one of two types:
  - Complete Data
  - Censored Data

- **Complete data** – the value of each sample unit is observed or known.

- **Censored data** – the time to the event of interest may not be observed or the exact time is not known.

CENSORED DATA

- Censored data can occur when:
  - The event of interest is death, but the patient is still alive at the time of analysis.
  - The individual was lost to follow-up without having the event of interest.
  - The event of interest is death by cancer but the patient died of an unrelated cause, such as a car accident.
  - The patient is dropped from the study without having experienced the event of interest due to a protocol violation.

Summary

- The Life table methodology was first adopted some 300 years back. Credit to Edmond Halley who used this statistical tool.
- Life table is an old method but is still being used to calculate some vital parameters.
- Types of Life table
- Modified life table
- Applications of Life table
- Limitations of Life Table


•THANK YOU