

Global Child Mortality: Status in 2008

Black RE, Cousens S, Johnson HL, Lawn JE, Rudan I, Bassani DG, Jha P, Campbell H, Fischer Walker C, Cibulskis R, Eisele T, Liu L, Mathers C, for the Child Health Epidemiology Reference Group of WHO and UNICEF. Global, regional, and national causes of child mortality in 2008: a systematic analysis. The Lancet. 5 June 2010; 375(9730): 1969-87.

Background and Introduction

- Despite declining child mortality, 8.8 million children under 5 years old (5q0) die annually.
- UN MDG 4 seeks to reduce mortality of 5q0 by two-thirds between 1990 and 2015.
- Many countries are not on track to meet this goal.
- Accelerated mortality decline is possible with expansion of targeted interventions.
- Frequently updated national data on causes of death (COD) can guide national & global priorities.

Background and Introduction

- 2000-2003: WHO and UNICEF's Child Health Epidemiology Reference Group (CHERG) undertook last comprehensive review of child mortality causes.
- The Countdown to 2015 Initiative used 2000-2003 estimates to assess the progress of 68 low & middle income countries toward MDG 4.
- More recent data & improved methods enabled updated estimates of cause-specific child mortality.
- We present estimates of the distribution of causes of child deaths in 2008 for 193 countries, with aggregated regional and global totals.

Summary of Methods

- Multicause proportionate mortality models to estimate deaths in neonates (0-27 days) & children (1-59 months).
- Selected single-cause disease models and analysis of vital registration (VR) data to estimate causes of child deaths.
- New national data from China and India instead of predictions based on global statistical models.
- Proportional COD estimated for 193 countries.
- Proportions applied to country-specific mortality rates in children under 5 (U5MR) and birth rates to calculate number of deaths by cause for countries, regions, & world.

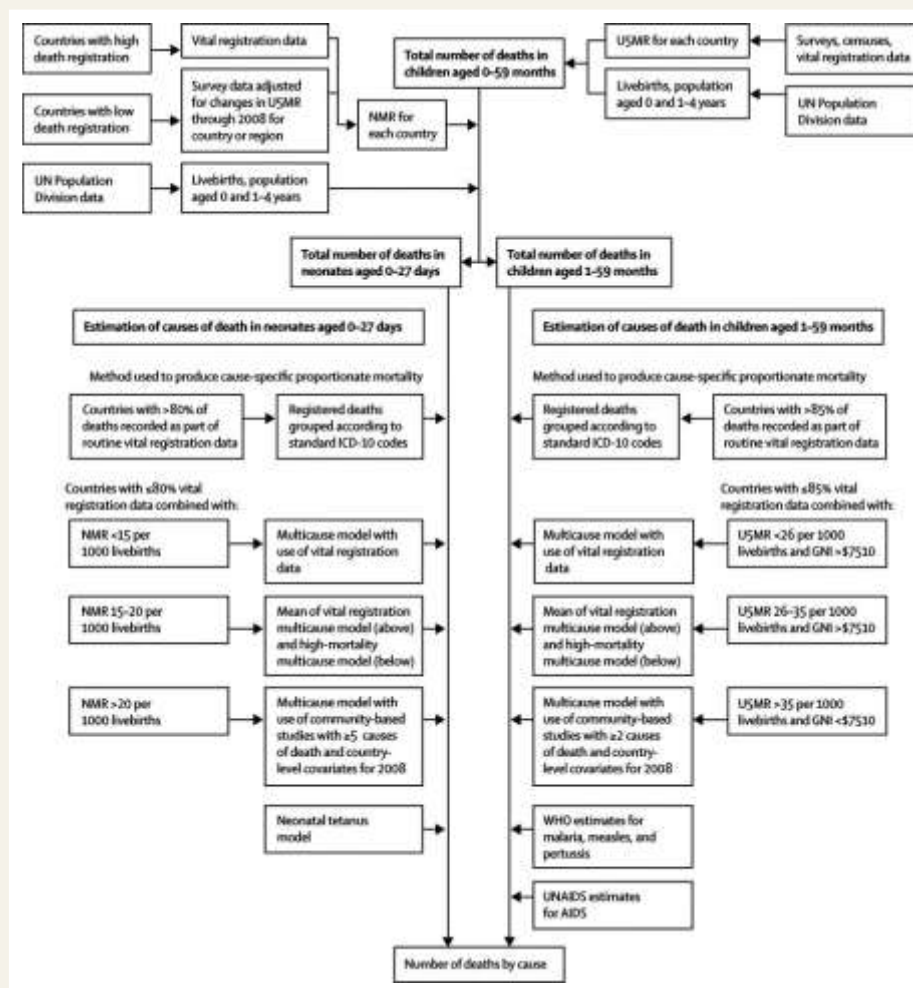
Under 5 Mortality Rates (U5MR)

- Inter-agency Group for Child Mortality Estimation (IGME) – annual country-specific U5MR estimates
- U5MR estimates used by CHERG are consistent, except:
 - when more recent death registration was available (several high income countries)
 - adjustment to correct for bias in survey data from deceased mothers (17 high HIV prevalence countries)
 - adjustment for misreporting of the date of birth and the estimated change in child deaths due to AIDS

Livebirths and Total Deaths

- UN Population Division, 2008 Revision
 - Estimated livebirths
 - De-facto numbers of children aged 0 & 1-4 years
- Total deaths in 5q0 for 2008 were estimated by application of the IGME-estimated mortality rates for children aged 0 and 1-4 years to the de-facto population for these age-groups.

Procedures for Estimation of Deaths by Cause in Children Under 5 (5q0)



U5MR=mortality rate in children younger than 5 years. NMR=neonatal mortality rate. GNI=gross national income per person (international dollars). ICD-10=International Classification of Diseases, 10th revision.

Neonatal Mortality Rates (NMR)

- Previous WHO estimation method revised to incorporate effect of projected change in 5q0 mortality rate through 2008.
- Low death registration coverage / suitable survey data:
 - regression model applied to data from 1990 onwards, after adjustment to match the estimated trend in the U5MR.
- No mortality rate data for neonates and 5q0
 - regression model run with aggregated regional data with regional fixed effects, rather than country-level fixed effects.

Analysis and Application of VR Data Extracted from WHO Mortality Database

- Adjusted for incomplete coverage, if needed
- Inclusion criteria for adequate death registration
 - 80% for neonates,
 - 85% for children 1-59 months
- Data closest to 2008 used (mean of closest 3-5 years used for very small countries)
- COD in neonates and children 1-59 months imputed from totals for children aged 0-4 years in a few cases (0.4% of deaths in 5q0)

Analysis and Application of VR Data Extracted from WHO Mortality Database

- Causes Categorized by International Classification of Diseases, 10th Revision (ICD-10)
- Reassigned if:
 - Cause was inappropriate to neonatal period
 - Cause was considered a congenital malformations (reassigned to congenital abnormality)
 - Deaths were reported with ill-defined causes

Analysis and Application of VR Data Extracted from WHO Mortality Database

- 3 models for countries with no useable death registration data
 - Low NMR (<15 neonatal deaths/1000 livebirths) by use of death registration data for low-mortality countries with adequate registration
 - High NMR (>20 neonatal deaths/1000 livebirths) as described below
 - When 15-20 neonatal deaths/1000 livebirths, both models were fitted and a mean of 2 results used

Causes of Death (COD) in Children 1-59 Months (inadequate VR data)

- <26 deaths/1000 livebirths in 5q0 or GNI/person >\$7510
 - multi-cause multinomial logistic regression model
 - death registration data (97 countries)
 - covariates for 5q0 mortality rates, GNI/person, & regional indicator variables for Europe & LAC
- 26-35 deaths/1000 livebirths in 5q0 & GNI/person >\$7510
 - mean of estimates from this model with those from model used for high-mortality countries

COD in High-Mortality Countries (inadequate VR data)

- Neonatal deaths (0-27 days)
 - Multicausal model revised to include additional study data from sites contributing data, and rerun with updated covariate data for 2008
 - Cause-specific results adjusted country-by-country to fit the estimated number of neonatal deaths for 2008

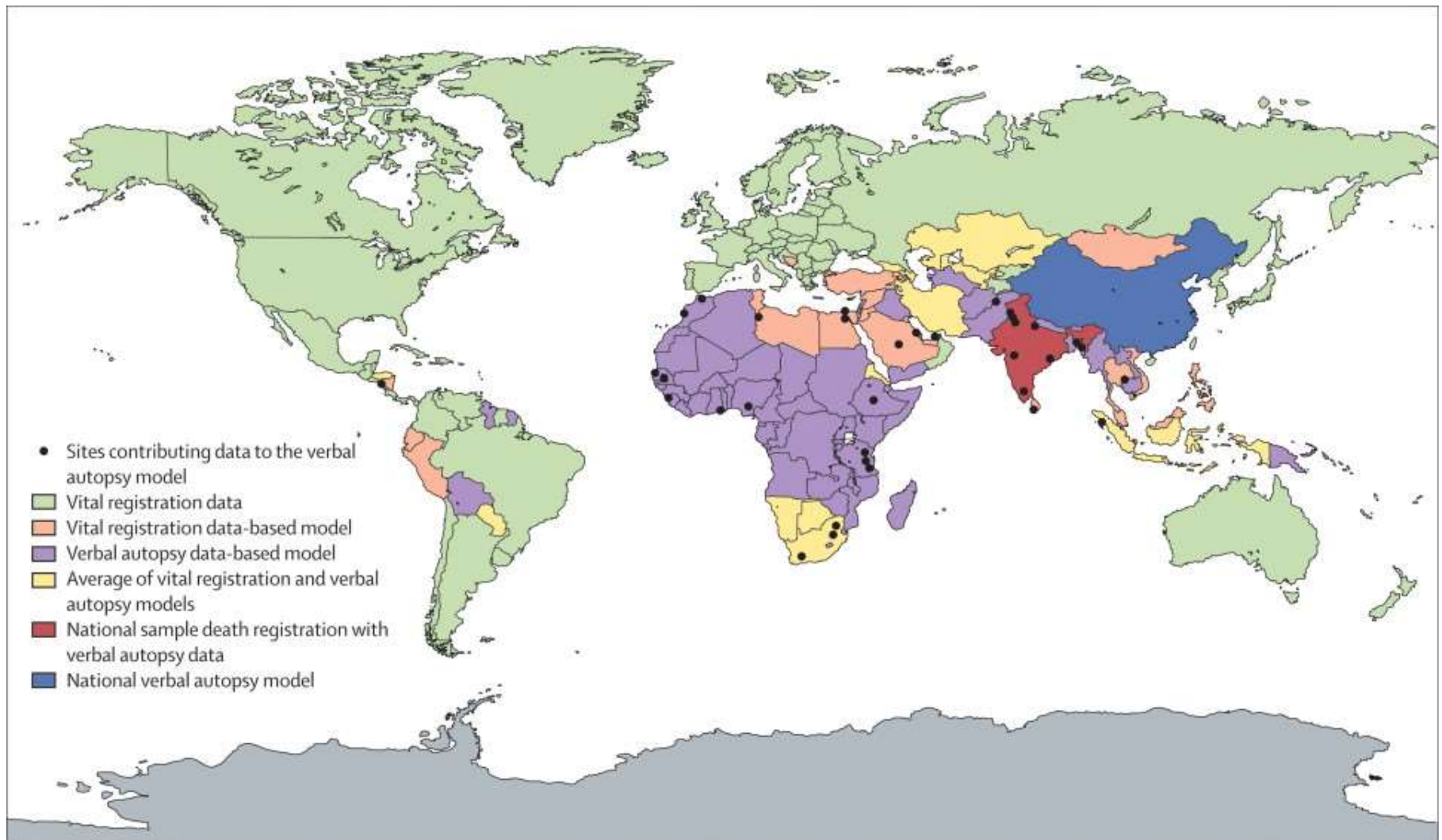
COD in High-Mortality Countries (inadequate VR data)

- Deaths in Children 1-59 months old
(≥ 35 deaths/1000 live births) & GNI/person \leq \$7510)
 - 81 datapoints from community-based mortality studies:
 - ≥ 2 COD were report in children 1-59 months
 - done after 1979 with 12 (or multiple of 12) month duration
 - ≥ 25 deaths in 5q0, with each death represented once
 - >25% of deaths due to unknown causes
 - 7 categories: pneumonia, diarrhea, malaria, injury, meningitis/encephalitis, measles, other known causes
 - Excluded neonatal, AIDS, or undetermined causes
 - “Malnutrition” reallocated to 1 of 5 infection categories

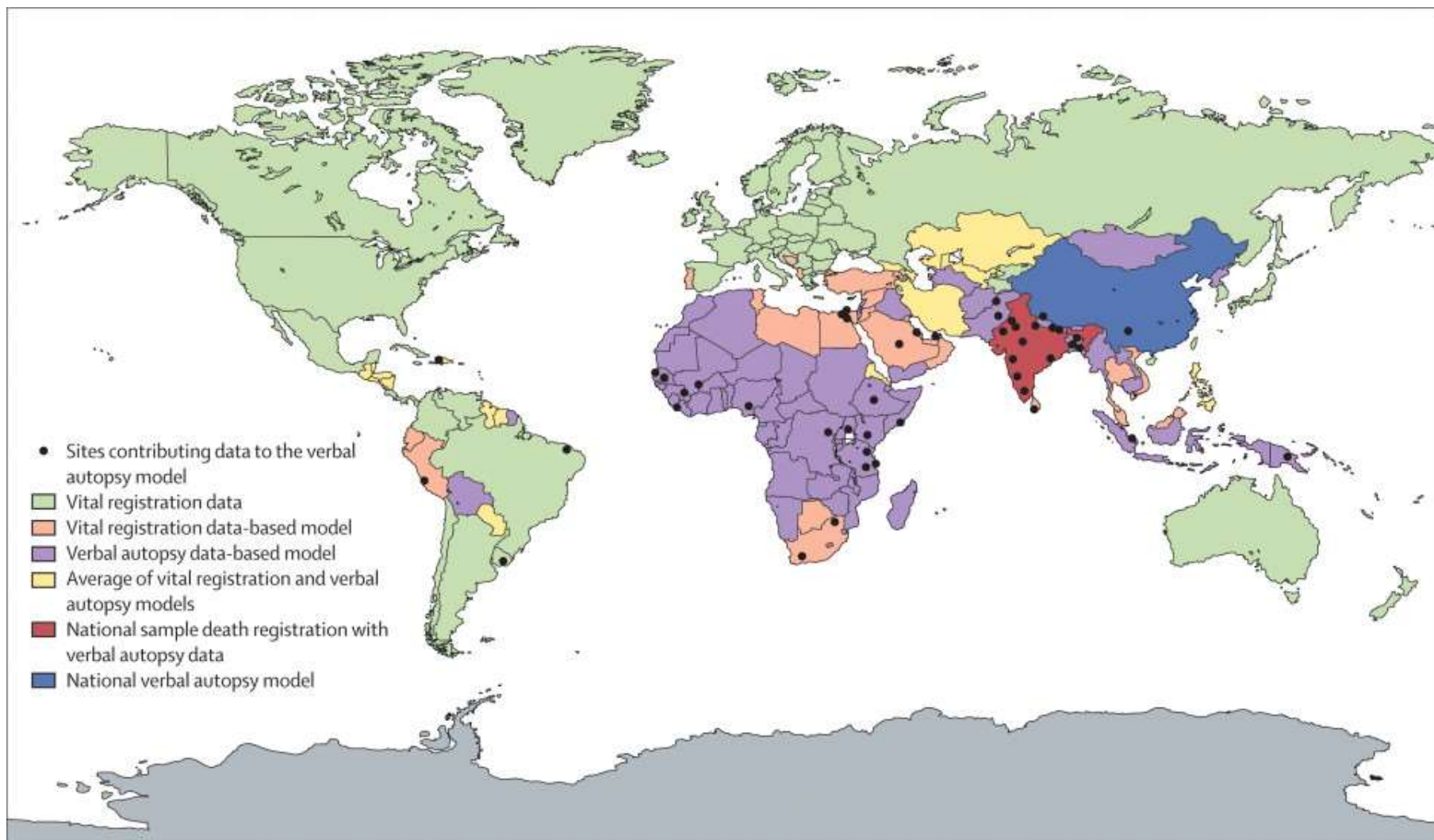
COD in High-Mortality Countries (inadequate VR data)- continued

- Multinomial logistic regression model applied to country-level data
- Country-level estimates of deaths by cause were:
 - adjusted for estimated effects of recently scaled up interventions:
 - use of Hib vaccine (pneumonia/meningitis estimates)
 - use of insecticide-treated bednets (malaria estimates)
 - combined with cause-specific data from WHO technical programs and AIDS deaths from UNAIDS
 - adjusted to the estimated total number of deaths in children aged 1-59 months

Methods Used to Estimate COD in Neonates



Methods Used to Estimate COD in Children Aged 1-59 Months



Deaths Due to Malaria, Pertussis, Measles, Tetanus, Meningitis, & AIDS

- **Malaria:** WHO World Malaria Report 2009
- **Pertussis:** WHO Dept of Immunization, Vaccines & Biologicals (IVB) by using WHO/UNICEF 2008 vaccination coverage estimates
- **Measles:** Revised natural history model
 - routine vaccination coverage & supplementary immunization activities
 - reported measles cases
 - estimates of notification efficiency
 - estimates of age-specific case-fatality rates.
- **Tetanus:** IVB/CHERG-developed statistical model based on WHO estimates of literacy in women, & proportions of births protected from tetanus & are delivered by SBA
- **AIDS:** UNAIDS-derived

COD in India

- India's Million Death Study (MDS)
 - nationally representative sample of > 23,000 child deaths in 2001-03
 - COD categorized & weighted by rural & urban subdivisions of each state
 - mean of estimates from MDS and natural history model to provide estimate of deaths due to measles
- Malaria Deaths - used WHO estimates
- Pertussis Deaths - used same method as for other countries
- Neonatal Deaths in India - estimated to account for 54% of deaths in 5q0 in 2008

COD in China

- Causes of child deaths
 - based on estimates of cause fractions as previously described
 - adjusted to estimates for total number of deaths in neonates & children aged 1-59 months in China in 2008.
- WHO technical program estimates for deaths caused by malaria, tetanus, pertussis, & measles
 - small proportions of child deaths
 - not generally included as specific causes in published data from China

Estimation of Uncertainty

- Jackknife analysis to estimate the standard error of the model's out-of-sample predictions
- Monte Carlo simulations (1000 iterations) to perturb country-level estimates based on standard errors
- Uncertainty ranges (URs) = 2.5 - 97.5 centiles
- Captures misclassification of deaths by verbal autopsy and the variability across studies
- Uncertainty estimates for AIDS, malaria, measles, pertussis, & tetanus were derived from single-cause disease models

Summary of Global Findings in 2008

8.795 million deaths in children < 5 years

68% (5.970 million) of deaths were from infectious diseases

Pneumonia	18%	1.575 million	1.046 - 1.874 million [UR]
Diarrhea	15%	1.336 million	0.822 - 2.004 million [UR]
Malaria	8%	0.732 million	0.601 - 0.851 million [UR]

41% (3.575 million) of deaths occurred in neonates

PTB Complications	12%	1.033 million	0.717-1.216 million [UR]
Birth Asphyxia	9%	0.814 million	0.563-0.997 million [UR]
Sepsis	6%	0.521 million	0.356-0.735 million [UR]
Pneumonia	4%	0.386 million	0.264-0.545 million [UR]

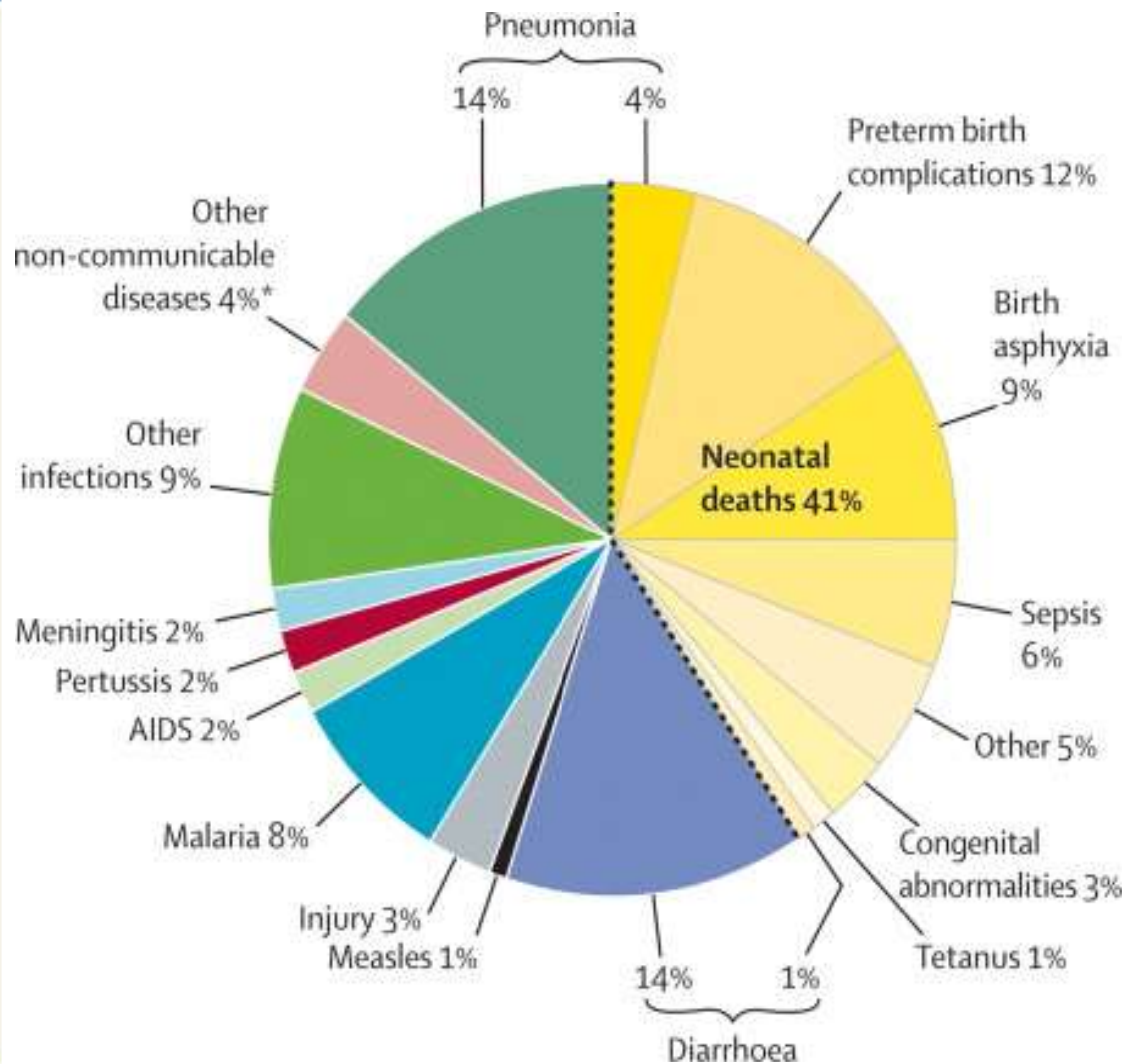
Estimated Global Deaths by Cause in Neonates (0-27 days) in 2008

Cause	Estimated Number	UR (in millions)
Preterm birth complications	1,033,000	(0.717 – 1.216)
Birth asphyxia	814,000	(0.563 – 0.997)
Sepsis	521,000	(0.356 – 0.735)
Other	409,000	(0.318 – 0.883)
Pneumonia	386,000	(0.264 – 0.545)
Congenital abnormalities	272,000	(0.205 – 0.384)
Diarrhea	79,000	(0.057 – 0.211)
Tetanus	59,000	(0.059 – 0.083)
Total	3,575,000	

Estimated Global Deaths by Cause in Children 1-59 months in 2008

Cause	Estimated Number	UR (in millions)
Diarrhea	1,257,000	(0.774 – 1.886)
Pneumonia	1,189,000	(0.789 – 1.415)
Other Infections	753,000	(0.479 – 2.830)
Malaria	732,000	(0.601 – 0.851)
Other NCD	228,000	(0.143 – 0.606)
Injury	279,000	(0.174 – 0.738)
AIDS	201,000	(0.186 – 0.215)
Pertussis	195,000	(???)
Meningitis	164,000	(0.110 – 0.728)
Measles	118,000	(0.075 – 0.180)
Congenital abnormalities	104,000	(0.078 – 0.160)
Total	5,220,000	

Distribution of Causes of Child Deaths: Global



Distribution of Deaths and Their Causes

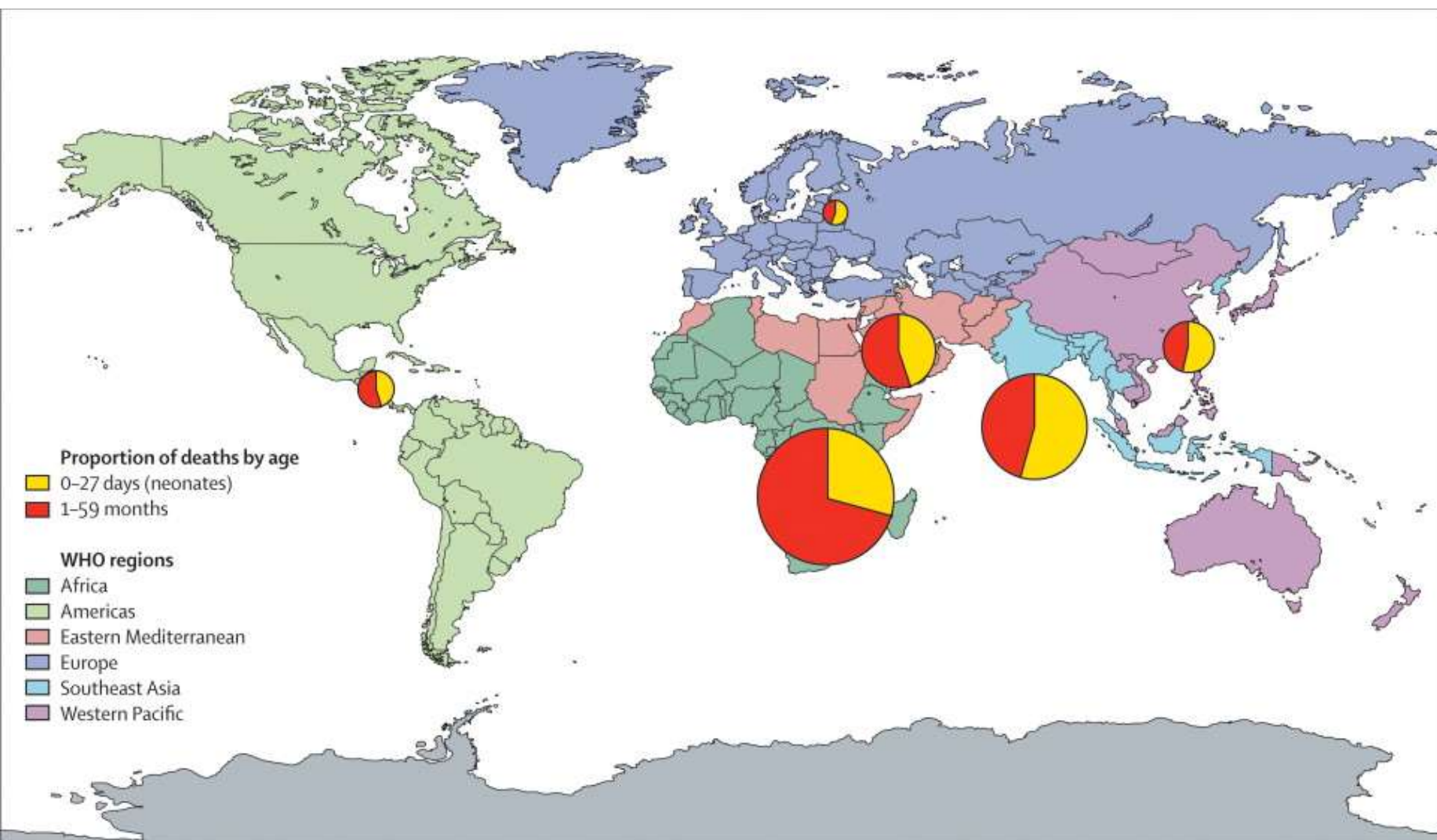
- Number of deaths varied widely across WHO regions - largest # deaths in:
 - African region (4.199 million)
 - southeast Asian region (2.390 million)
- Differing patterns of COD:
 - lower proportion of **neonatal deaths** in African region (29%, 1.224 million) than in southeast Asian region (54%, 1.295 million)
 - higher proportion of deaths in Africa due to **malaria** (16%, 0.677 million) & **AIDS** (4%, 0.181 million) than in southeast Asia (1%, 0.024 million due to two causes combined)

Distribution of Deaths and Their Causes

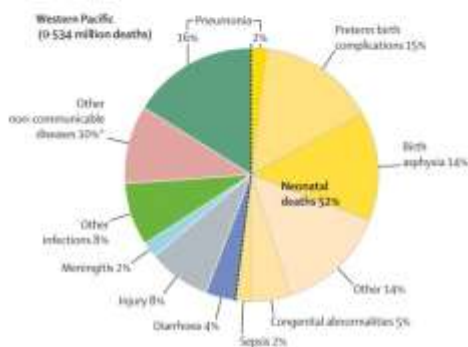
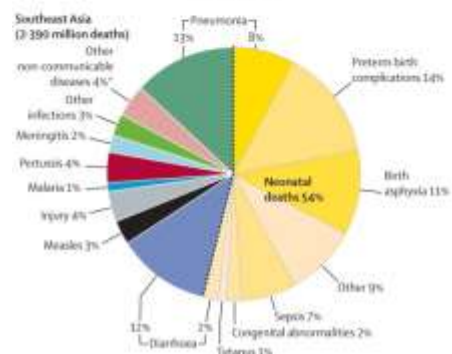
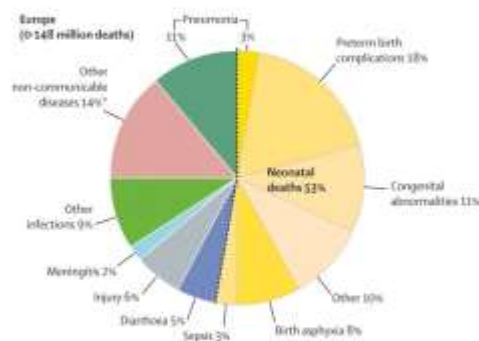
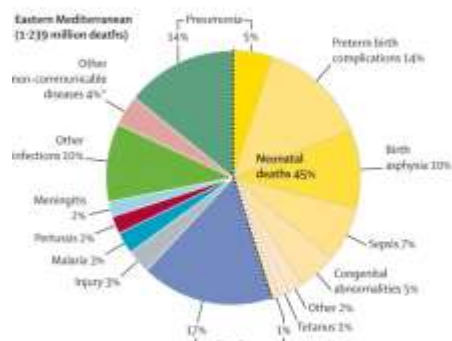
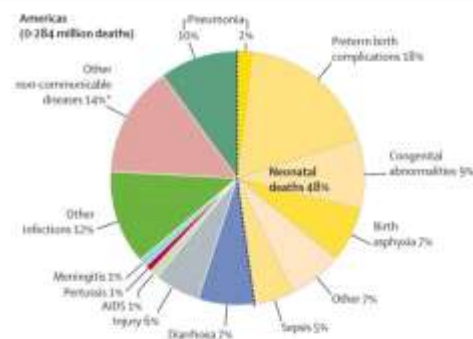
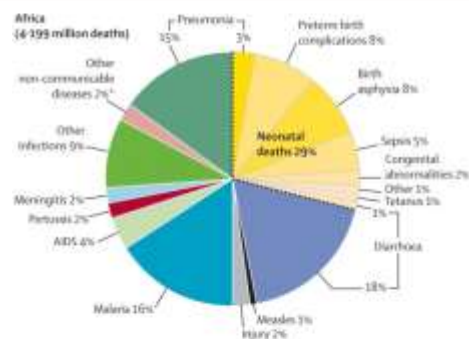
- In the Americas, Europe, Asia:
 - High proportion of deaths during neonatal period
 - 48% (0.137 million/0.284 million) in the Americas
 - 54% (1.295 million/2.390 million) in southeast Asia
 - Leading causes:
 - preterm birth complications
 - birth asphyxia
 - Congenital causes became proportionately more important in countries with low neonatal mortality

Child Deaths by WHO Region (and age)

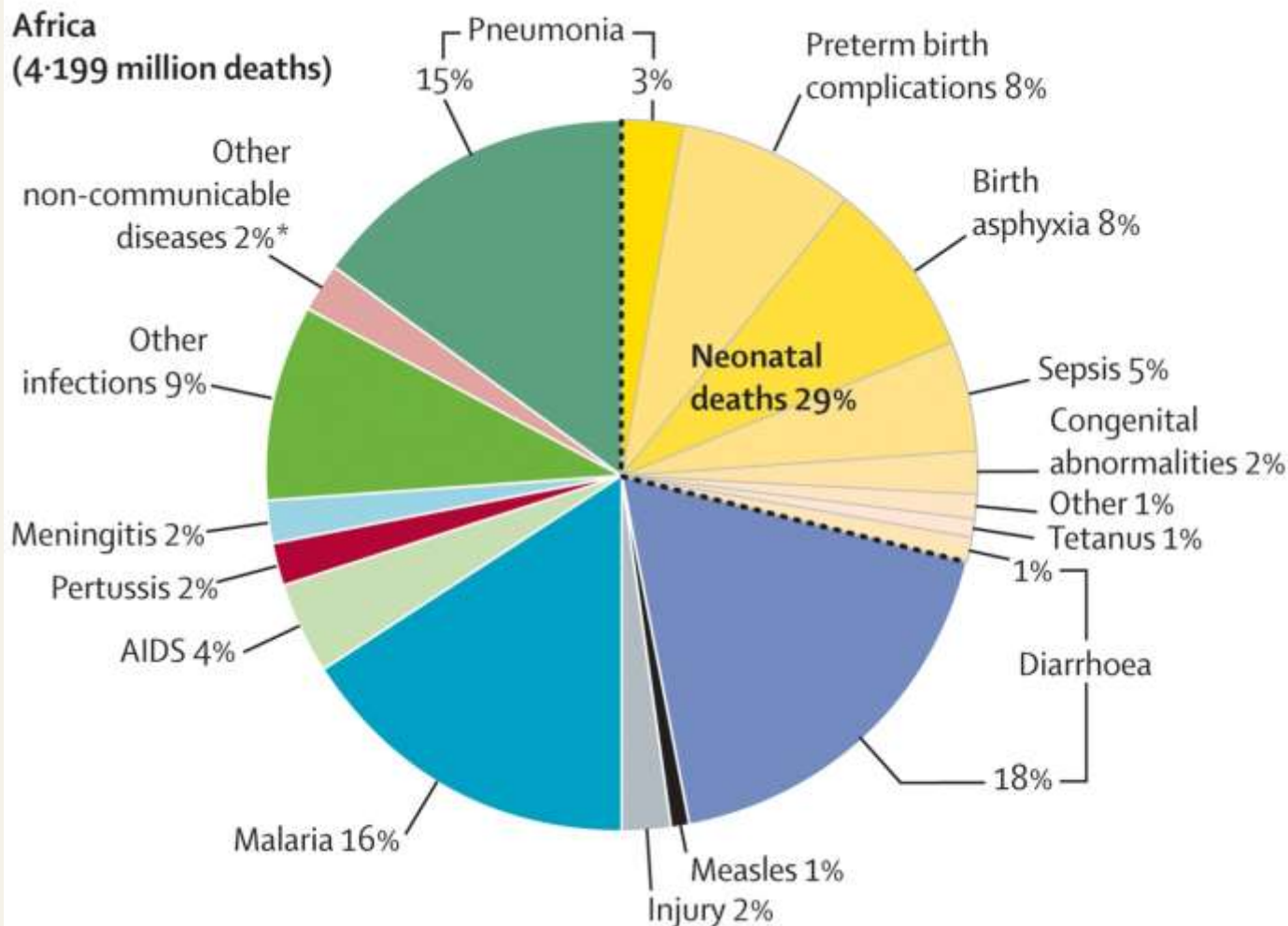
8.8 Million in 2008



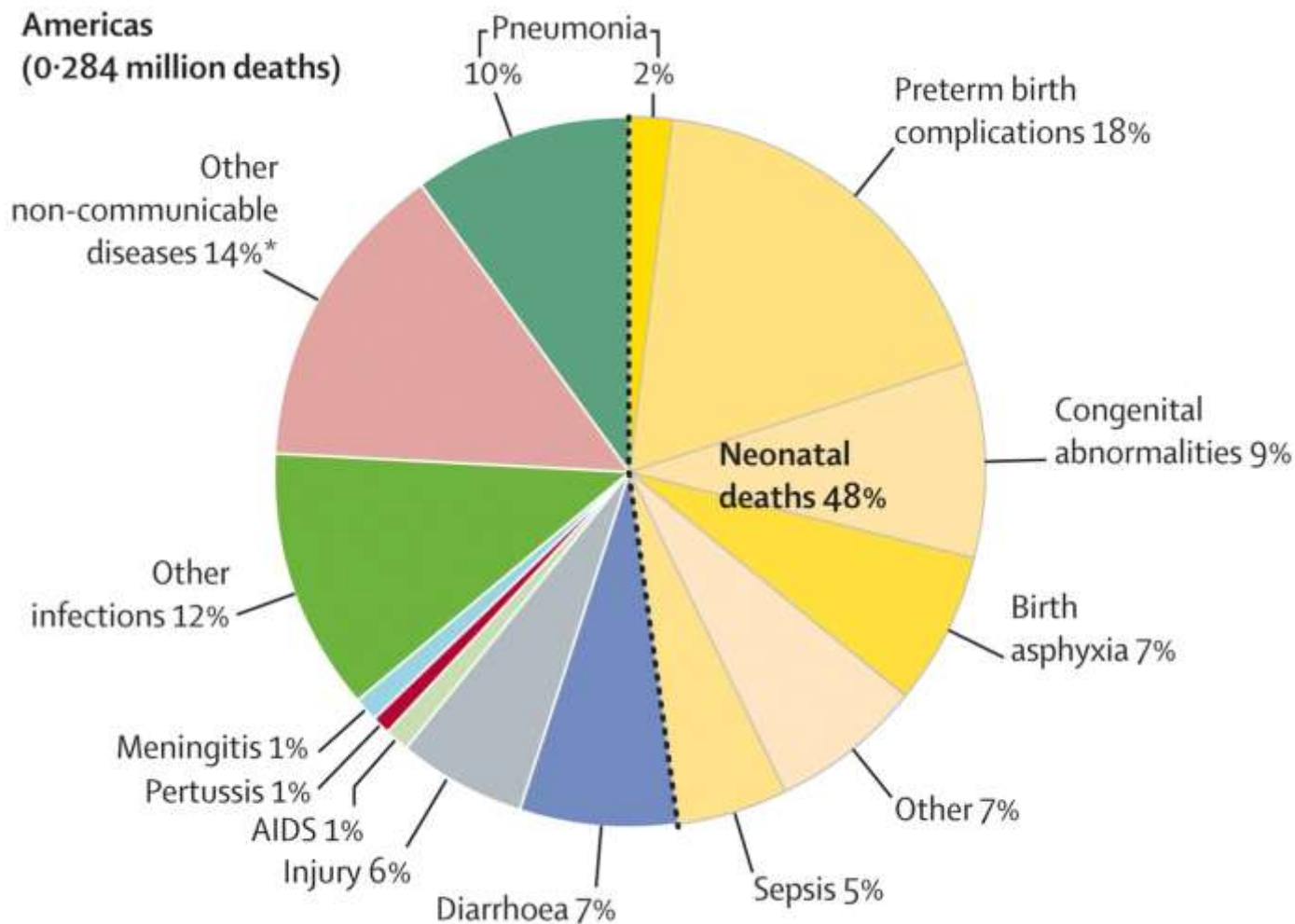
Causes of Child Deaths (by region)



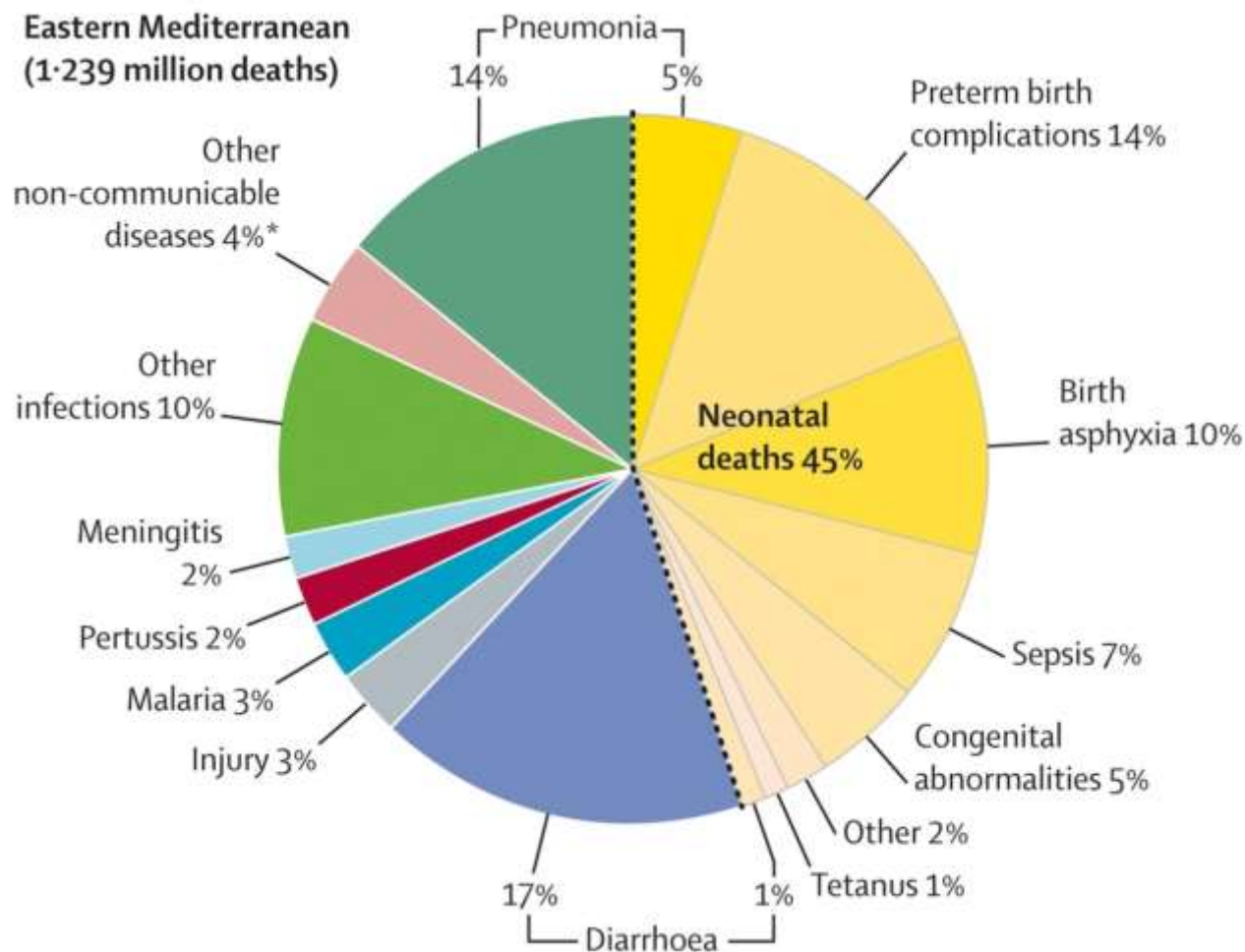
Distribution of Causes of Child Deaths: Sub-Saharan Africa



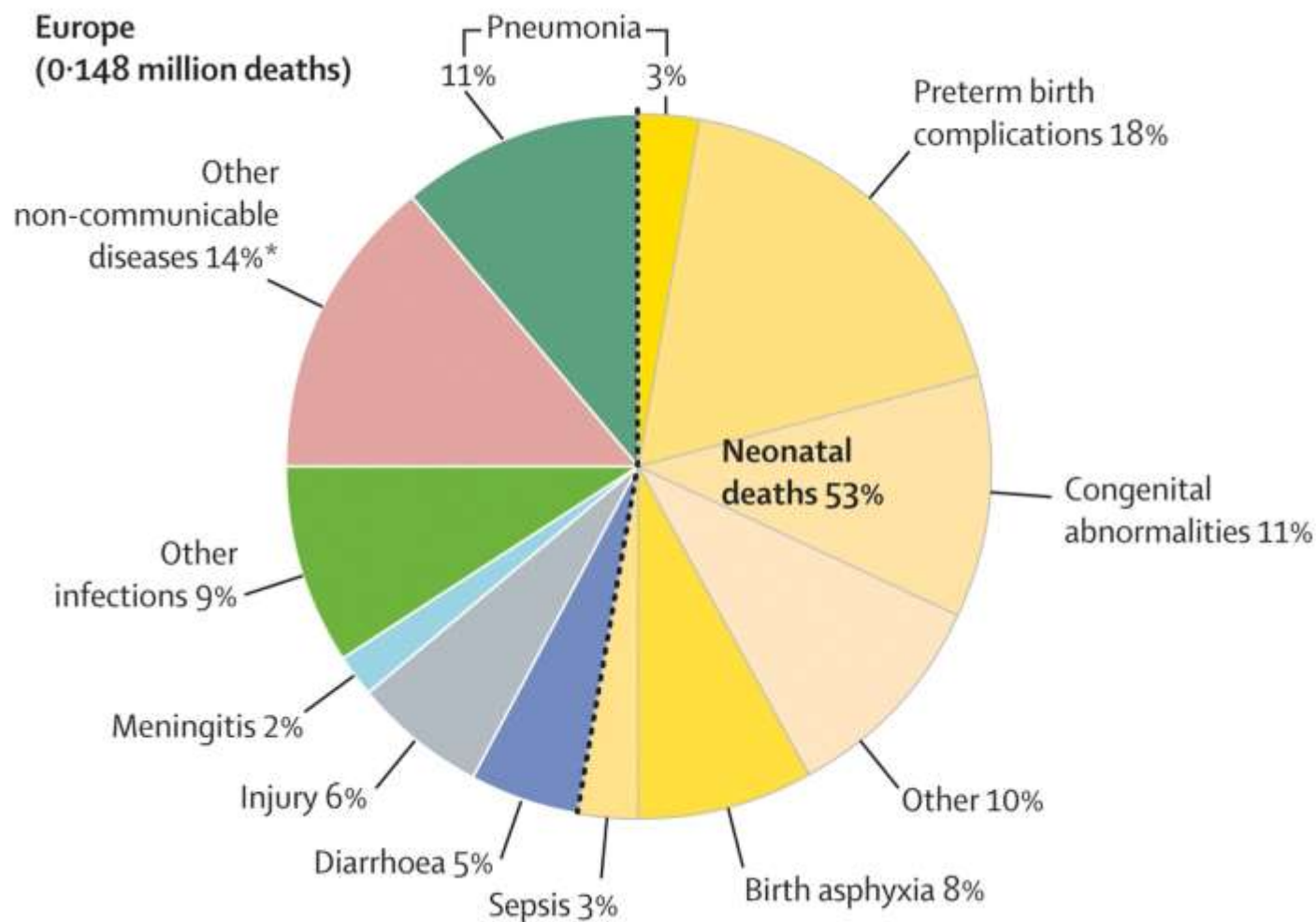
Distribution of Causes of Child Deaths: Americas



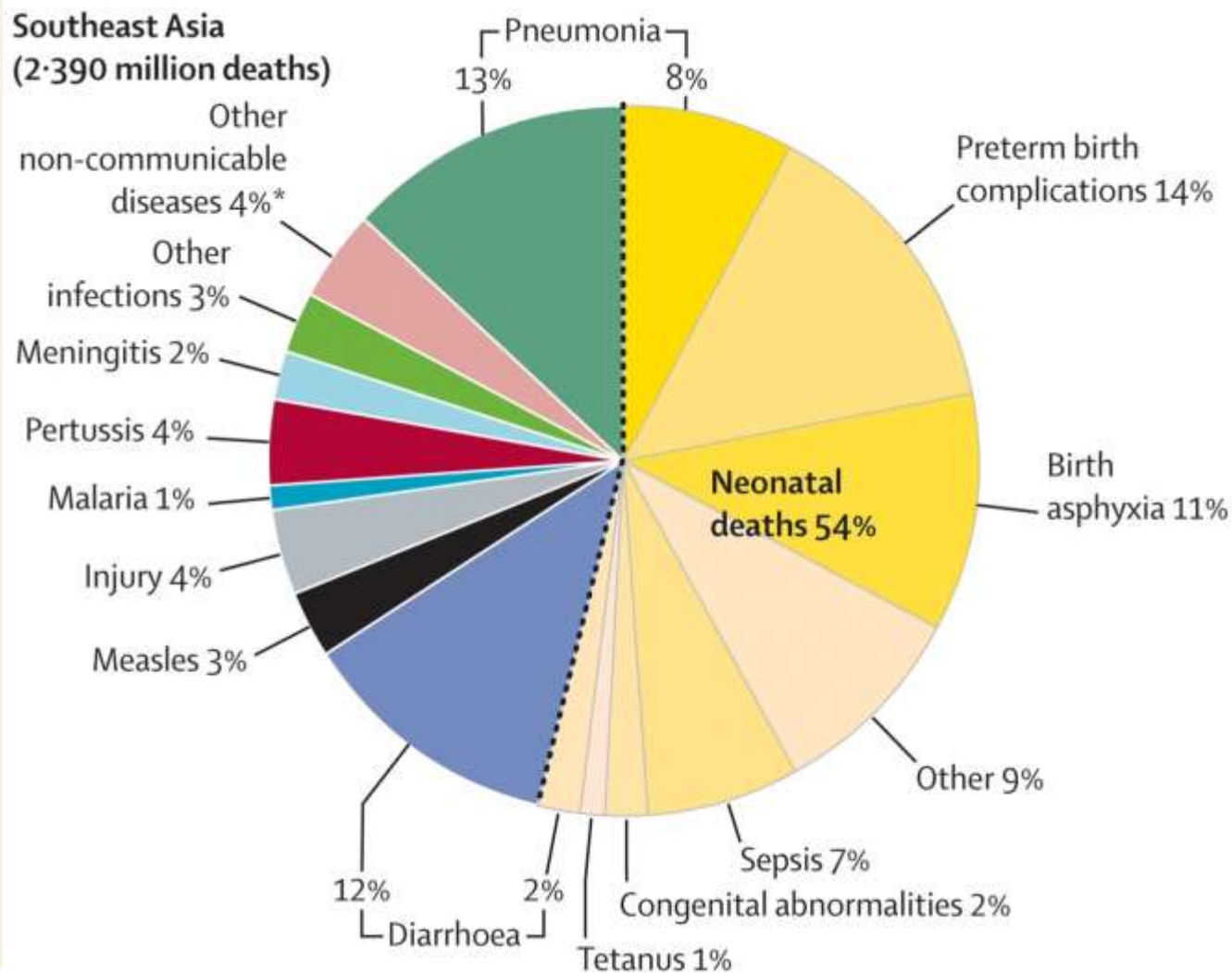
Distribution of Causes of Child Deaths: Eastern Mediterranean



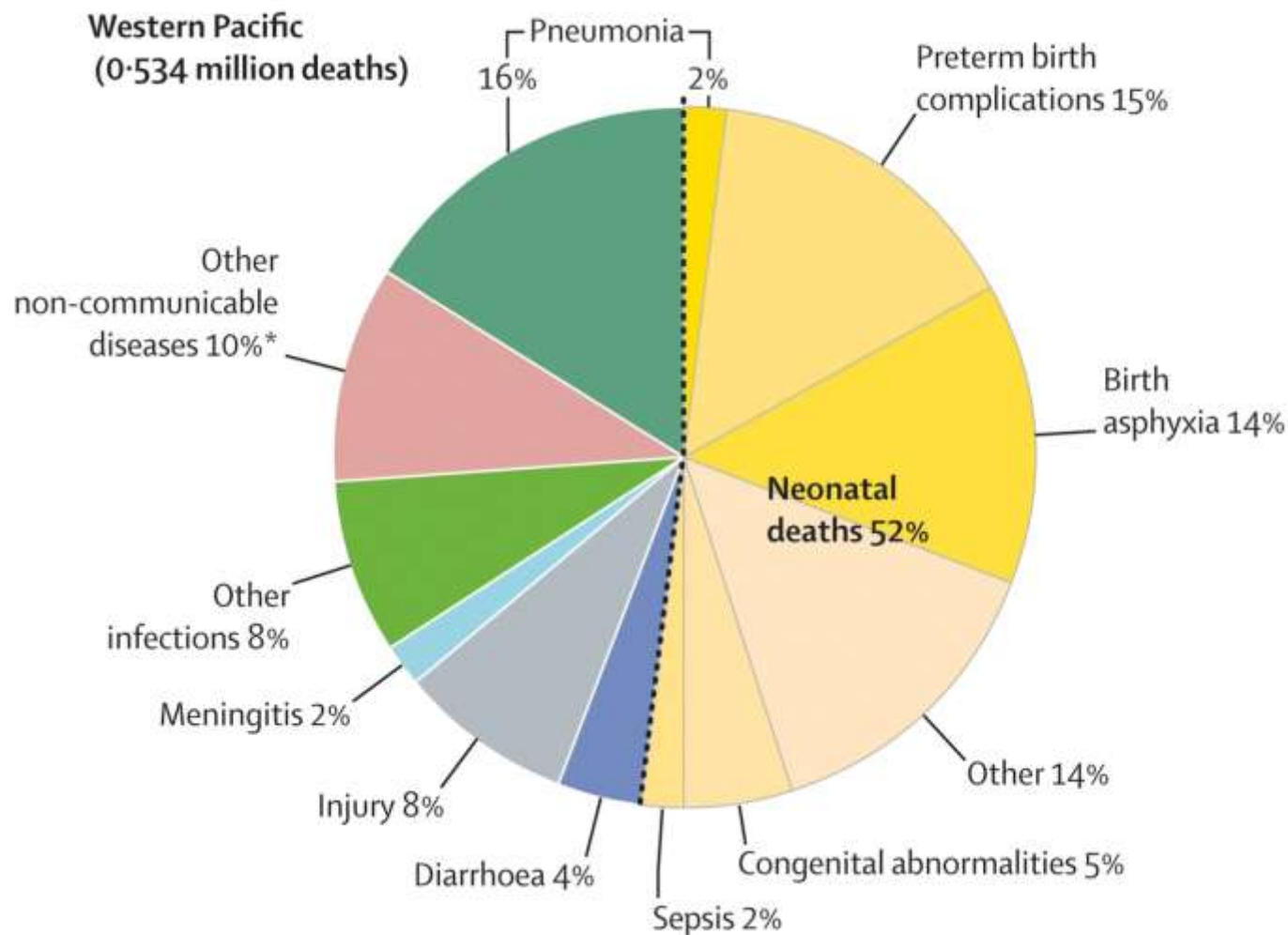
Distribution of Causes of Child Deaths: Europe



Distribution of Causes of Child Deaths: Southeast Asia



Distribution of Causes of Child Deaths: Western Pacific



Results

- All children under 5 years (5q0) – for 193 countries
 - most important single COD:
 - pneumonia
 - diarrhea
 - preterm birth complications
 - other important causes: birth asphyxia & malaria
 - the African region accounted for:
 - 92% (0.677 million) of deaths due to malaria
 - 90% (0.181 million) of deaths due to AIDS
 - measles and tetanus each responsible for ~1% of deaths (successful vaccination programs)

India, Nigeria, Pakistan, China and Democratic Republic of Congo (DRC)

- 43% (274.392 million) of all 5q0
- **49% (4.294 million) of all 5q0 deaths in 2008**
- High proportions of global totals for neonatal COD

Cause	Percent	Estimated #
Birth asphyxia	53%	0.443 million
Sepsis	52%	0.271 million
Preterm Birth Complications	49%	0.521 million
Congenital Abnormalities	43%	0.161 million

India, Nigeria, Pakistan, China and Democratic Republic of Congo (DRC)

- 52% (0.826 million) of deaths caused by **pneumonia**
 - India, Nigeria, DRC, Pakistan, and Afghanistan
- 51% (0.676 million) of deaths caused by **diarrhea**
 - India, Nigeria, Afghanistan, Pakistan, Ethiopia
- 57% (0.417 million) of deaths caused by **malaria**
 - Nigeria, DRC, Uganda, Sudan & Tanzania (all SSA)
- 51% (0.103 million) of deaths due to **AIDS**
 - South Africa, Nigeria, Mozambique, Tanzania, Uganda
- **Injuries** important in nearly all countries
 - 32% (0.093 million) of deaths in India and China

All Children Under 5 Years Old

- Collectively, infectious diseases are most important COD.
- Most important single causes are pneumonia, diarrhea, and preterm birth complications.
- Numbers of deaths varied widely across WHO regions (most deaths I Africa and southeast Asia).
- Despite continuing increase in population of 5q0, mortality rate is declining (8.8 million in 2008 vs. 10.6 million/year during 2000-2003).

Neonates

- 40% of < 5 deaths occurred in neonatal period
- Greatest single causes of neonatal death:
 - preterm birth complications
 - birth asphyxia
 - infectious diseases
- Greater declines in mortality in 1-59 month old children, so proportion of deaths in neonates increased:
 - 37% in 2000-03
 - 41% in 2008 (3.6 of 8.8 million <5 deaths)

Diarrhea and Pneumonia

- Most important COD in children aged 1-59 months currently and in previous estimates
- Percentage of < 5 deaths attributable to each cause has reduced by 20-25%
 - Smaller proportion of deaths occurring in children aged 1-59 months
 - New data show previous estimate of deaths due to diarrhea in China was too high (12% vs 3.1%)
- Additional data & changes in analytical methods result in more accurate estimates, but not a true indication of a time trend for certain diseases.

Discussion

- Concentration of all-cause child deaths and deaths due to some specific causes, such as diarrhea, pneumonia, malaria, and AIDS, in a small set of countries is striking.
 - large populations of 5q0 in these countries
 - epidemiological/social conditions concentrate some diseases
 - successful disease control in these countries is essential for achieving MDG 4 goals
- Nearly all countries face challenge to reduce child deaths from preventable conditions, irrespective of number/cause.
- These national COD estimates (2008) should help to identify priority interventions for child survival, and how to allocate national and international resources.

Undernutrition

- Not presented as a direct COD
- Is an underlying cause in 1/3 of deaths in 5q0
 - Includes stunting, severe wasting, Vitamin A and zinc deficiencies and suboptimal breastfeeding
 - Malnutrition is rarely listed as COD & verbal autopsy classification systems underestimate role
 - Few deaths reported caused by malnutrition were allocated to infectious diseases that often precipitate severe wasting.
- Successful implementation of interventions to prevent undernutrition and micronutrient deficiencies and to treat severe acute malnutrition would reduce child mortality.

Major Changes in Estimation Methods in 2008 Compared with 2000-2003

- New estimates of national mortality rates in children < 5 years and in neonates
- Multicause models increased datapoints (102→148)
- National data used for India and China
- Multicause model used instead of single-cause models for age-group of 1-59 months (similar to previous multicause neonatal model)

Major Changes in Estimation Methods in 2008 Compared with 2000-2003

- Modeled estimates adjusted for recent scale-up of hib b vaccine and insecticide-treated bednets
- Estimates of AIDS, neonatal pneumonia and sepsis, meningitis, pertussis, and NCD added to previously presented causes
- Provision of uncertainty bounds for global numbers of child deaths from major causes

Limitations

- Scarcity of COD data in highest U5MR countries
 - Medically certified vital registration available for 76 countries (4% of 8.8 million <5 deaths)
 - Evidence gap most acute for sub-Saharan Africa
 - Where mortality rates and need for data are the highest, resources and data are the lowest
- Estimates derived from statistical modelling include substantial uncertainty, but are useful for planning national health and nutrition efforts.

Interpretation

- Country-specific estimates of major COD should help focus national programs & donor assistance.
- Achievement of MDG 4 (to reduce child mortality by 2/3) is only possible if high numbers of deaths are addressed by maternal, newborn, and child health interventions.
- CHERG will update these estimates every year to complement annual updates in total deaths in children younger than 5 years.

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