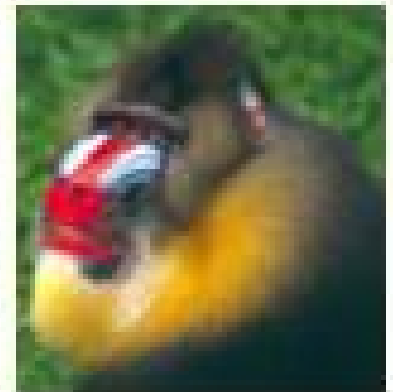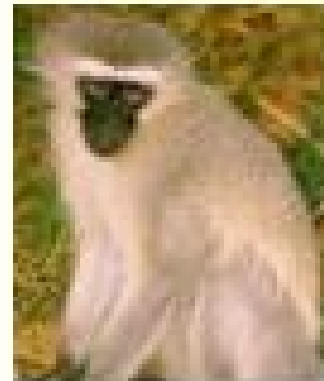# HIV transmission dynamics

M&E Workshop for AIDS Program Managers

Cape Town, 10-11 January 2008

Prof. Thomas M. Rehle, MD, PhD

Features of SIV/HIV evolution:

- Cross-species transmission
- Fast rate of evolution
- Recombination

- monkey to monkey
- monkey to chimpanzee
- monkey to human (HIV-2)
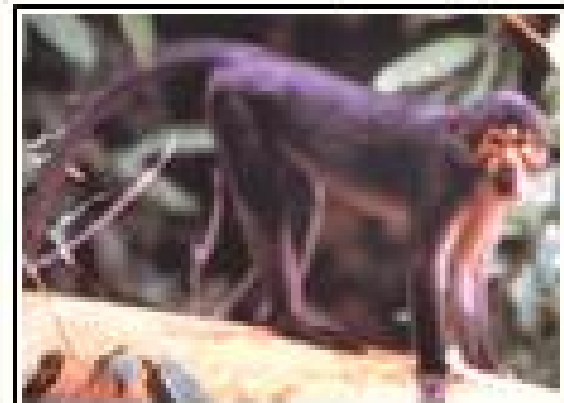- chimpanzee to human (HIV-1)

'Where AIDS came from'

HIVs derived from SIVs infecting other primates

HIV-1 from chimpanzees

HIV-2 from sooty mangabeys

Where ?
How often ?

SIV in chimpanzees ??

3 origins of HIV-1

Group M
global pandemic

Group N
very rare

Group O
rare

- SIVcpzCAM13] Cameroon
- SIVcpzGAB1] Gabon
- HIV-1 M/A
- HIV-1 M/B
- SIVcpzCAM3] Cameroon
- SIVcpzCAM5
- SIVcpzUS
- HIV-1 N
- HIV-1 N
- SIVcpzGAB2] Gabon
- HIV-1 O
- HIV-1 O
- SIVcpzDRC1] DRC
- SIVcpzTAN1] Tanzania
- SIVcpzTAN2
- SIVcpzTAN3
- SIVcpzTAN5
- SIVcpzANT
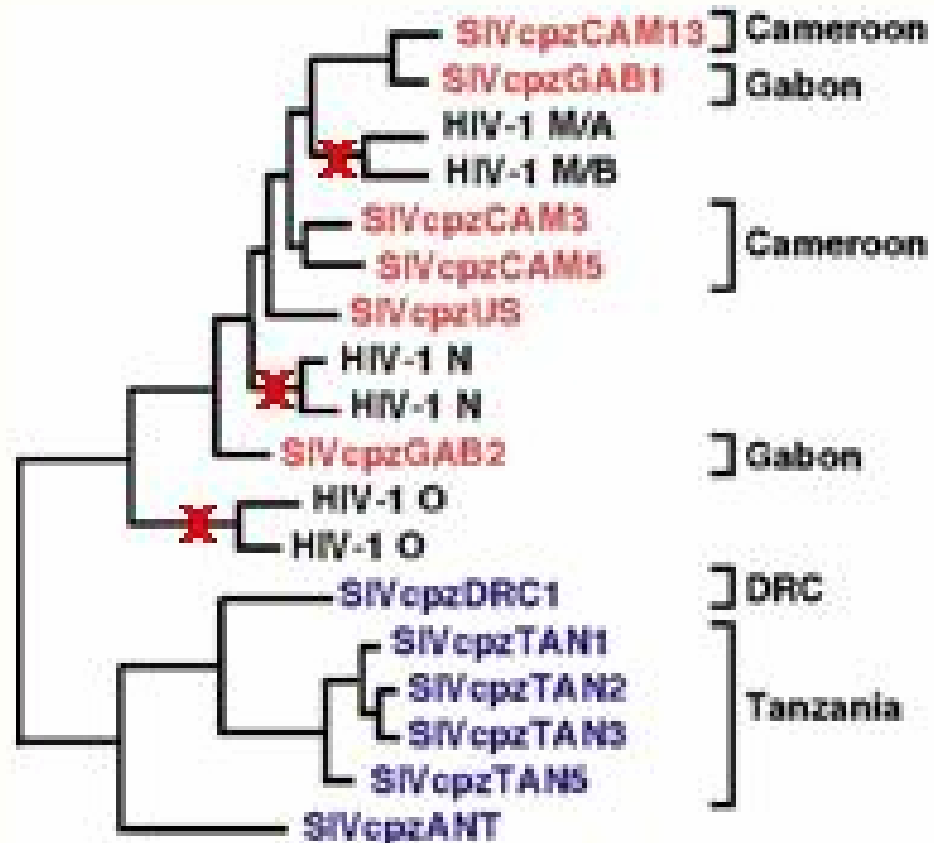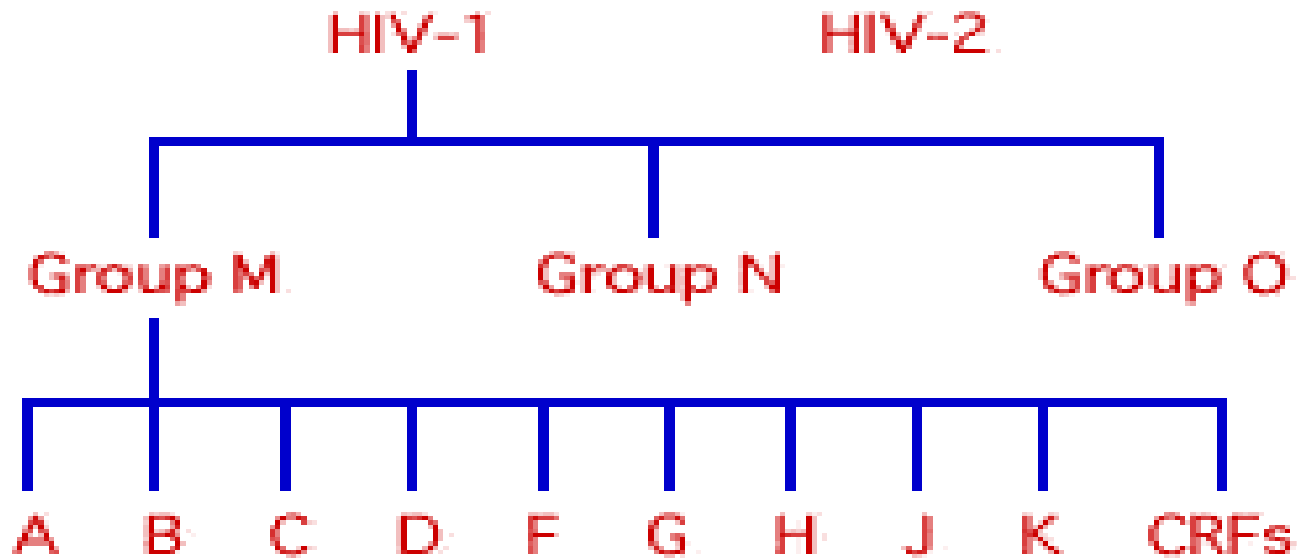
This diagram illustrates the different levels of HIV classification. Each type is divided into groups, and each group is divided into subtypes and CRFs.

Distribution* of HIV-1 *env* subtypes in the WHO African Region, 2000
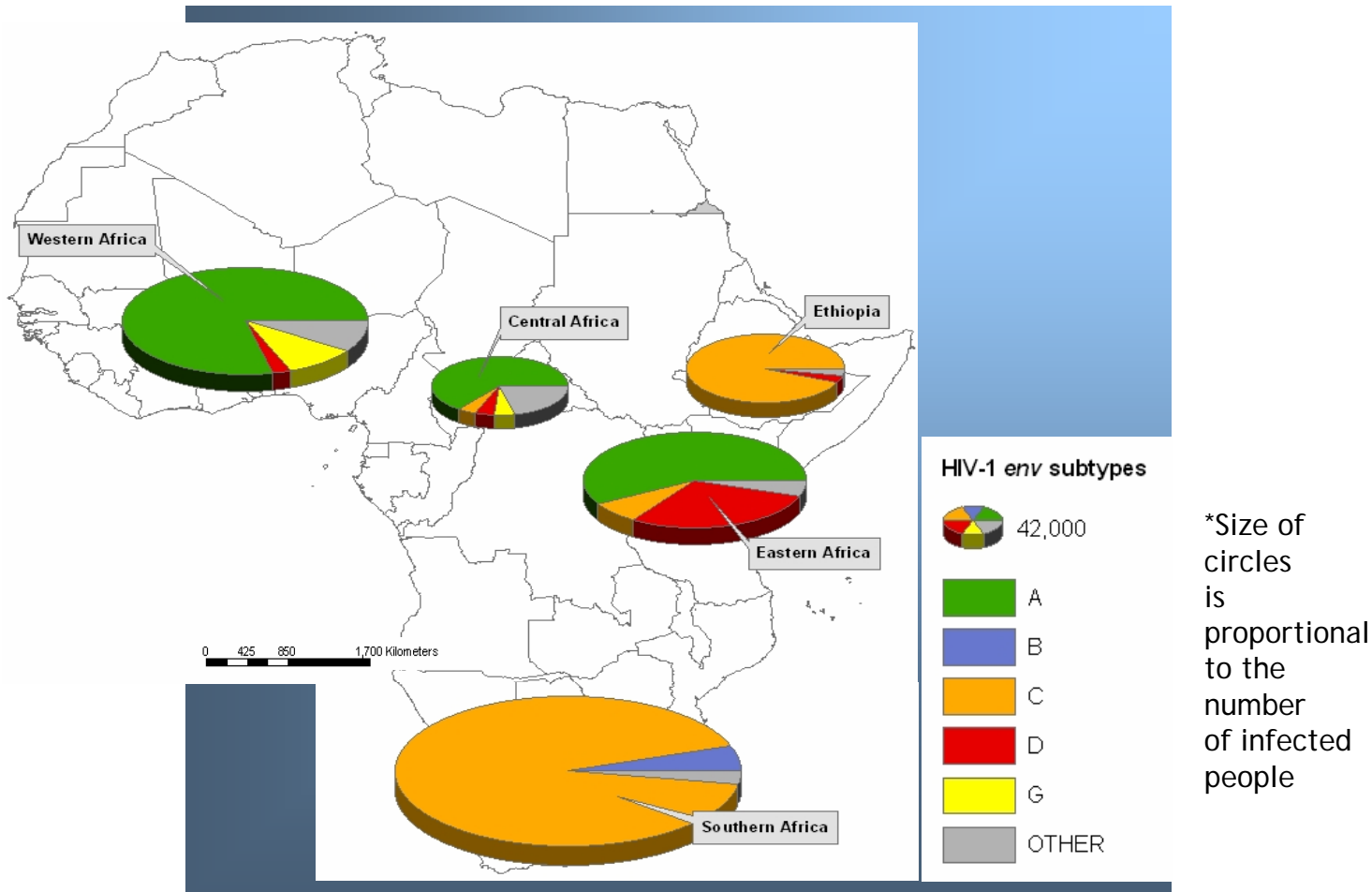
Figure 10

HIV viral load and infectivity at various stages of infection
(M Cassell & A Surdo; Lancet 2007)

HIV RNA (Log$_{10}$ copies per mL) vs Stage of disease

- 1/25–1/1000 (at peak during Seroconversion/Acute infection)
- 1/1000–1/10000 (Asymptomatic infection)
- 1/100–1/1000 (HIV progression)
- 1/50–1/1000 (AIDS)

Stages: Seroconversion / Acute infection (3 weeks); Asymptomatic infection (years); HIV progression (falling CD4 count); AIDS
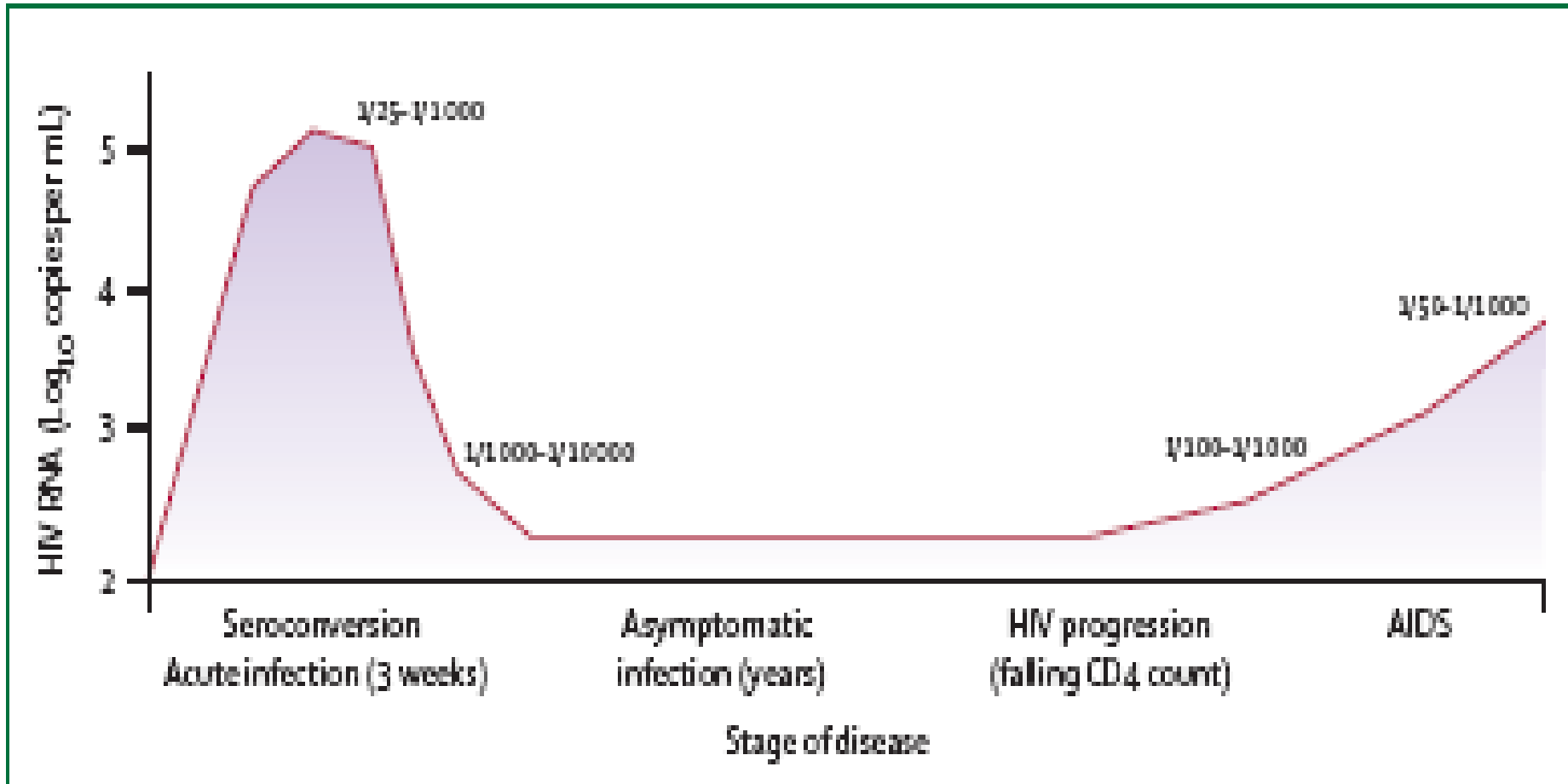
Prevalence = incidence X average duration

New infections

Prevalence

Deaths
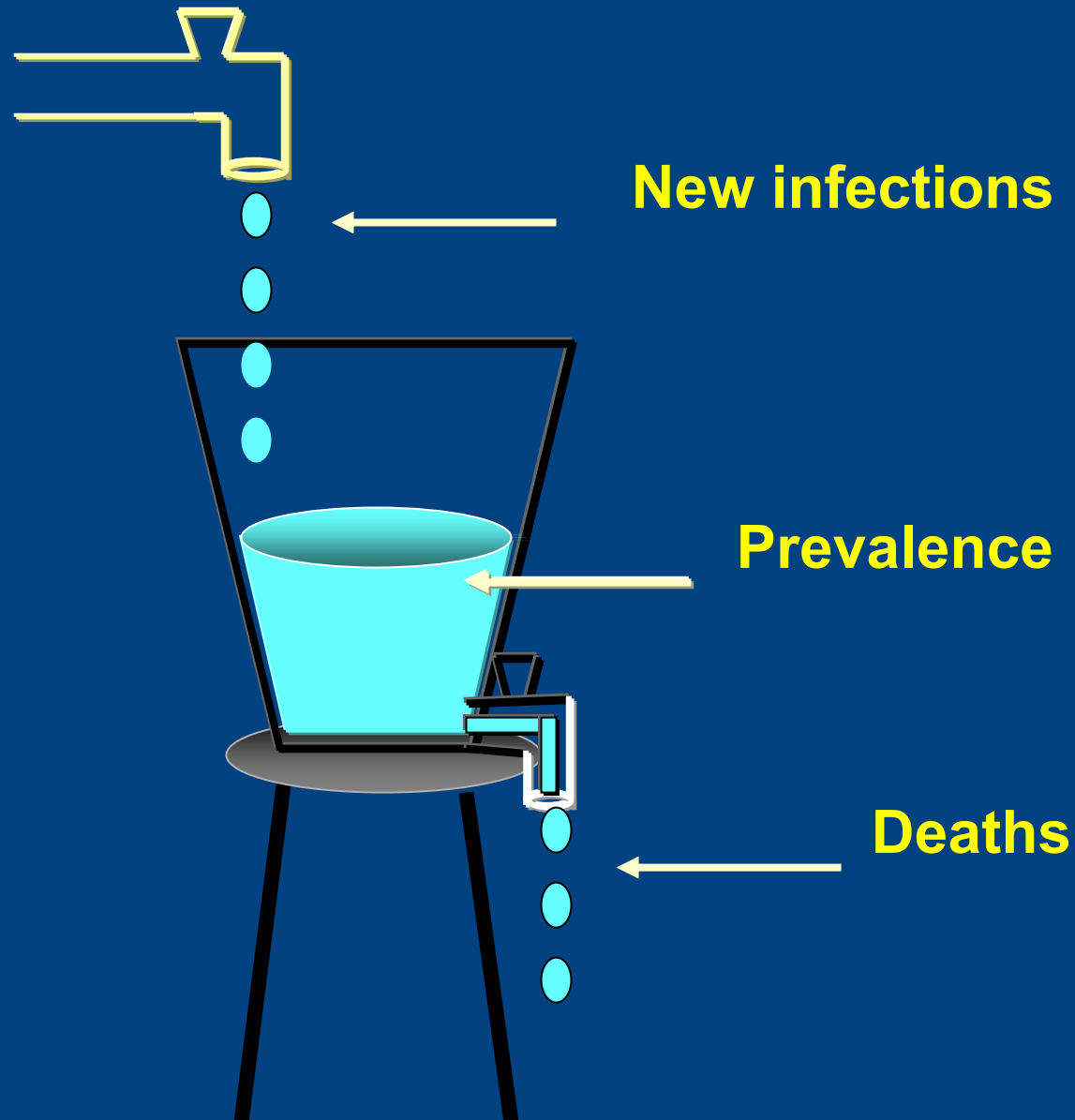
Basic reproductive rate R_o

$R_0 = \beta c D$

β = Average probability of HIV transmission per exposure to an infectious partner

c = Number of exposures of susceptible persons to infectious partners per unit time

D = Duration of infectious period

Basic Reproductive Rate

>1

"ALL"
INFECTED

(BRR = 2)

1 ⟶ 2 ⟶ 4 ⟶ 8 ⟶ 16 ⟶ 32 ⟶ ∞

Basic Reproductive Rate

< 1
DISEASE DIES OUT

(BRR = $\frac{1}{2}$)

4 ⟶ 2 ⟶ 1 ⟶ < 1 ⟶ < 1 ⟶ 0
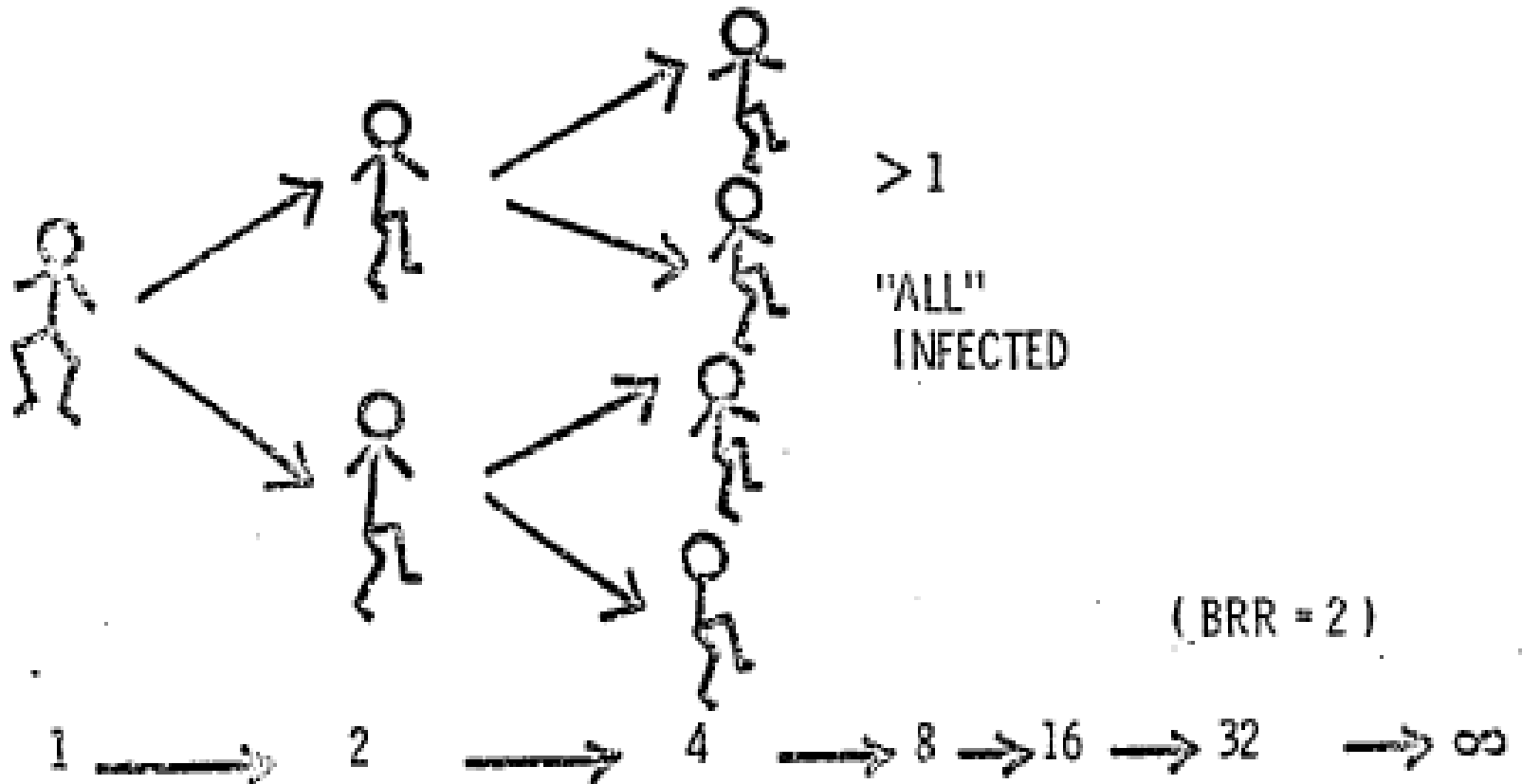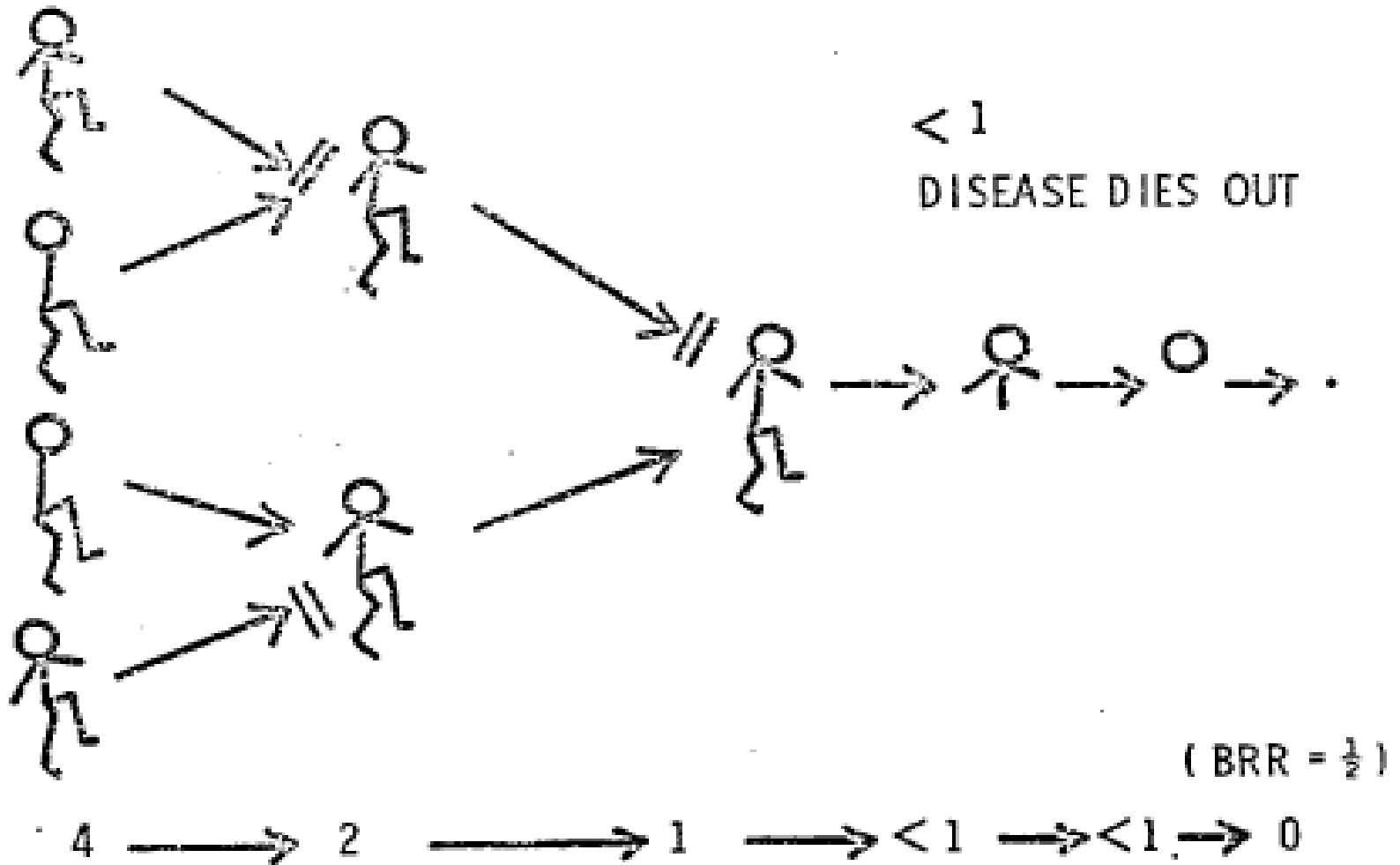
Relationship between incidence, prevalence, and mortality

HIV EPIDEMIC STAGES

Factors facilitating HIV spread

$$\boxed{\text{C: Number of exposures of susceptible persons to infected persons per unit time}} \; \times \; \boxed{\beta \text{: Efficiency of transmission per contact}} \; \times \; \boxed{\text{D: Duration of infectious period}} \; = \; \boxed{\text{HIV incidence and prevalence}}$$
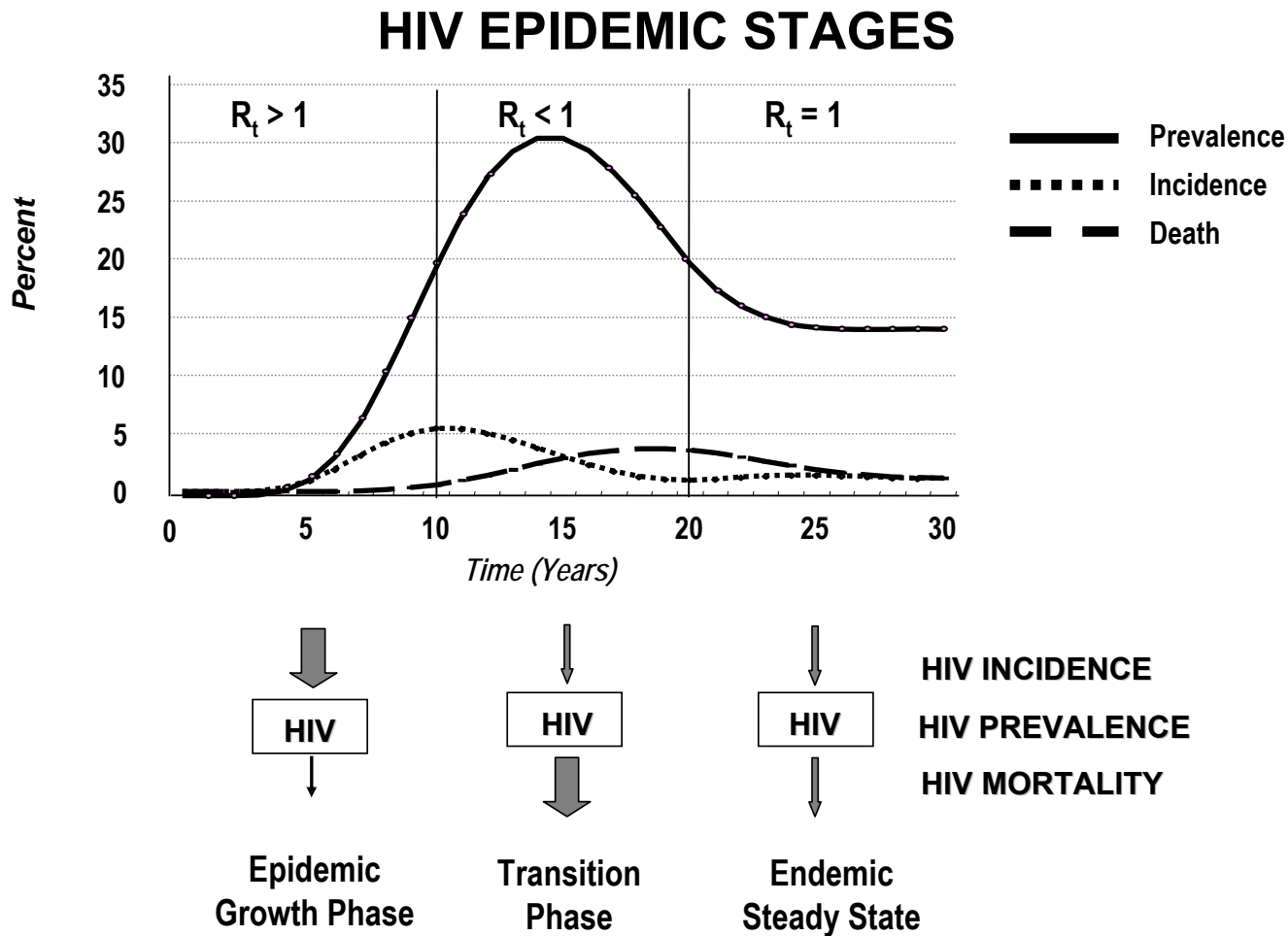
Factors inhibiting HIV spread

Factors facilitating HIV spread

•HIV prevalence
•Poverty
•Urbanization
•Gender imbalance
•Cultural context
•Stigma

•Multiple partners
• Mixing patterns
• Concurrent partners

•Concurrent STI
•Risky sexual practices
•Viral load
•Anal sex

Mortality

•ART (prolonging survival time)
•Basic care
•Prophylaxis

Community level   **Individual level**

C: **Number of exposures of susceptible persons to infected persons per unit time**

X

β: Efficiency of transmission per contact

X

D: Duration of infectious period

=

HIV incidence and prevalence

Community level   **Individual level**

•Intervention programs
•Religious and cultural norms
•Literacy

•Abstinence
•Faithfulness
•Sequential partners
•Delayed sexual debut

•Condom use
•Circumcision
•ART (reduction of viral load) Chemotherapy
•Early STI treatment

•Lack of basic care
•Concomitant infections (TB)

Factors inhibiting HIV spread

Second generation HIV surveillance

M&E Workshop for AIDS Programme Managers

Cape Town, 10-11 January 2008

Prof. Thomas M. Rehle, MD, PhD

Critical Questions

Are the observed changes in the prevalence of HIV:
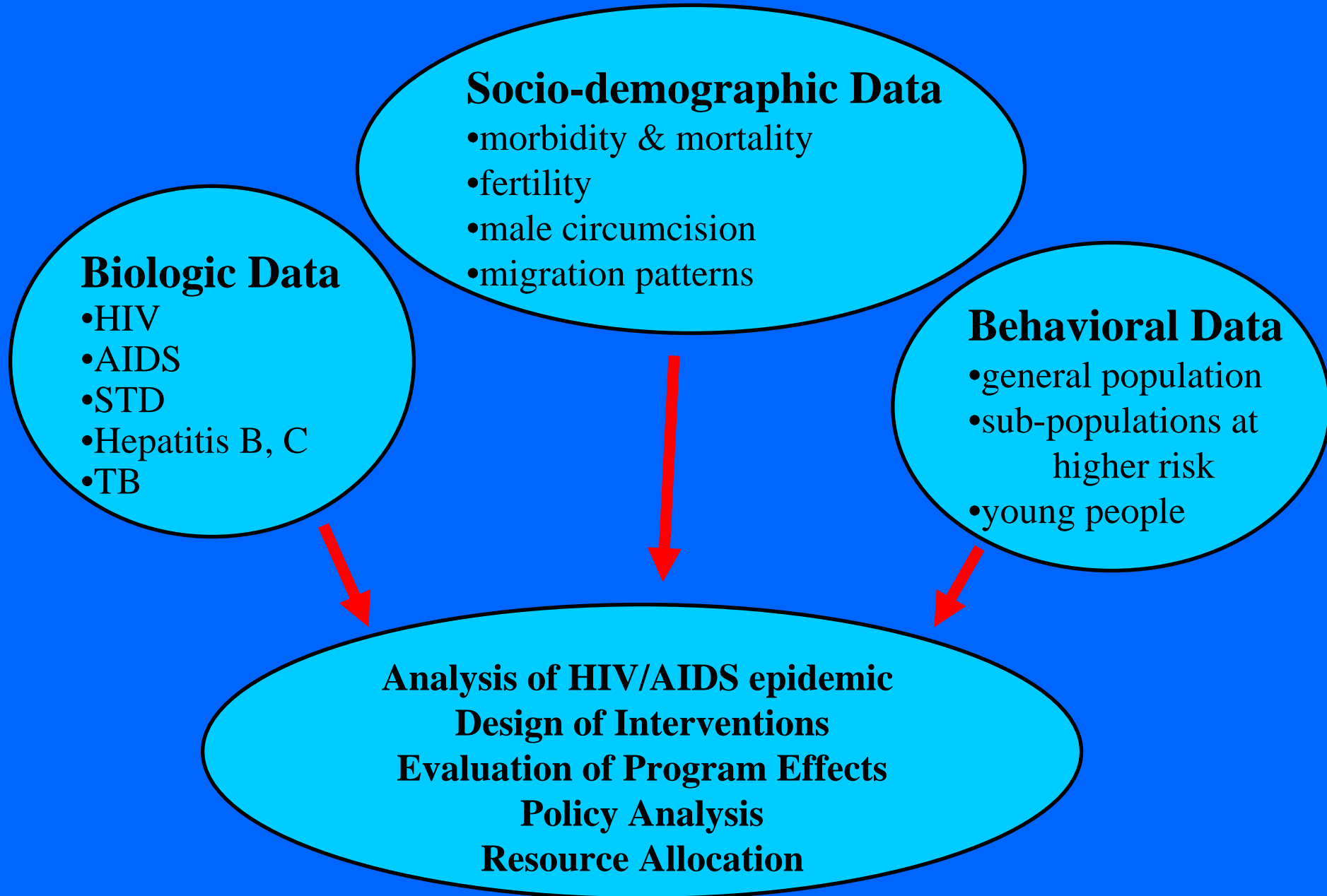
1. a reflection of the natural history of the epidemic?

2. a product of changes in behavior?

3. a product of interventions?

Factors Contributing to Observed Changes in HIV Prevalence

- **Mortality, especially in mature epidemics**

- **Saturation effects in populations at high infection risk**

- **Decrease in new HIV infections as a result of behavior change:**
  - **Effect of interventions**
  - **Spontaneous (e.g. close friend with HIV/AIDS)**

- **Decrease in the prevalence of biological cofactors e.g. STIs**

- **Decrease in deaths in HIV infected persons as a result of antiretroviral therapy (ART)**

- **Population differentials related to in- and out migration patterns**

- **Sampling bias and/or errors in data collection**

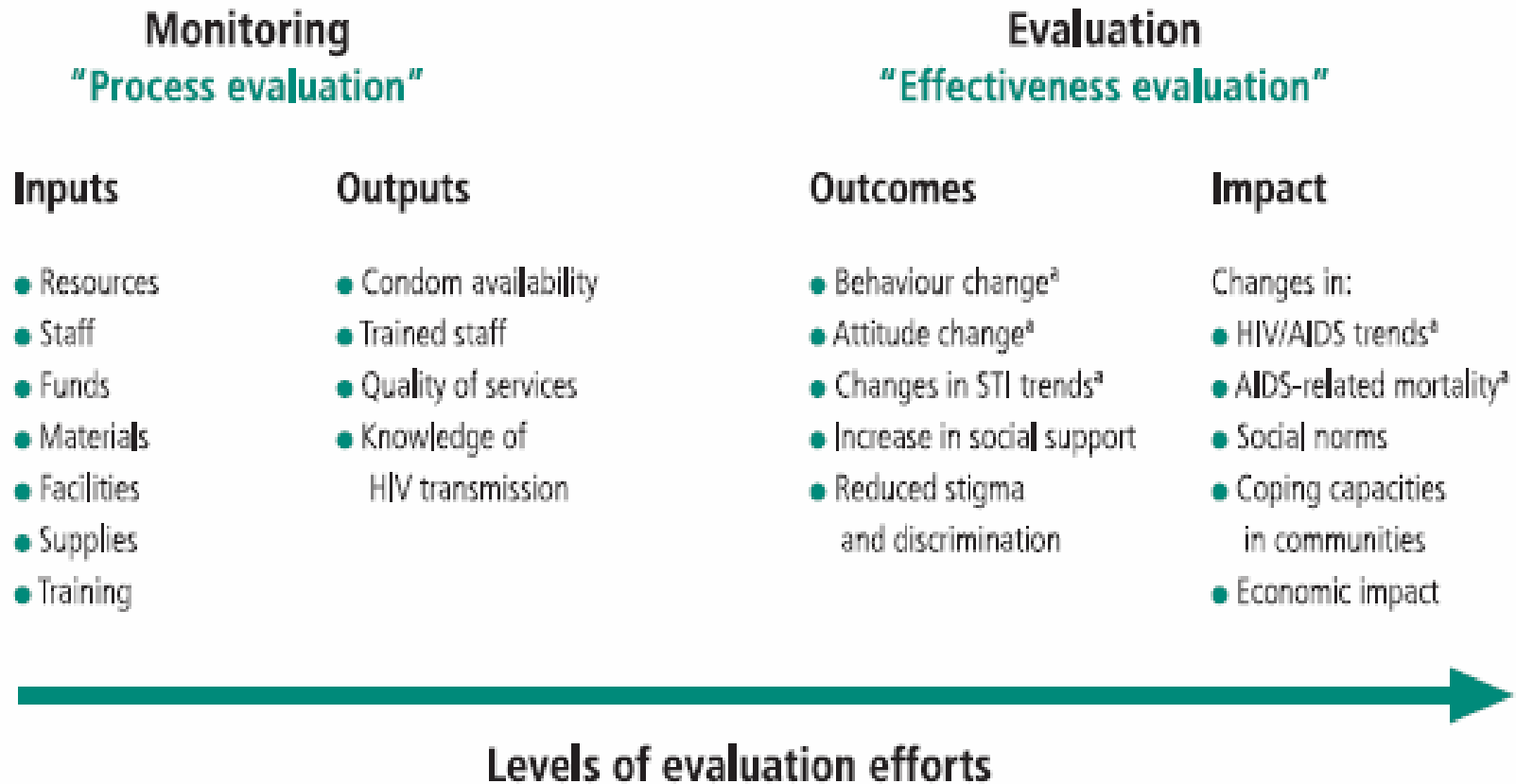# Data for Improved Analysis and Decision Making

Socio-demographic Data
- morbidity & mortality
- fertility
- male circumcision
- migration patterns

Biologic Data
- HIV
- AIDS
- STD
- Hepatitis B, C
- TB

Behavioral Data
- general population
- sub-populations at higher risk
- young people

Analysis of HIV/AIDS epidemic
Design of Interventions
Evaluation of Program Effects
Policy Analysis
Resource Allocation

Some milestones….

- **WHO 1988: Sentinel surveillance in antenatal clinics**

- **FHI & UNAIDS 1998: Joint workshop on behavioral data collection needs**

- **UNAIDS / WHO 2000: Guidelines for second generation HIV surveillance**

- **South Africa 2002: Nelson Mandela / HSRC HIV household survey**

Key features of second generation HIV surveillance

- biological (HIV, AIDS, STI) and behavioral surveillance are integral components
- adapted to stage and type of the epidemic
- surveillance more focused on sub-populations at high risk of infection
- emphasis on trends over time

Fig. 2. **Framework of monitoring and evaluation efforts**

Monitoring
"Process evaluation"

Evaluation
"Effectiveness evaluation"

Inputs	Outputs	Outcomes	Impact
• Resources	• Condom availability	• Behaviour change[a]	Changes in:
• Staff	• Trained staff	• Attitude change[a]	• HIV/AIDS trends[a]
• Funds	• Quality of services	• Changes in STI trends[a]	• AIDS-related mortality[a]
• Materials	• Knowledge of	• Increase in social support	• Social norms
• Facilities	HIV transmission	• Reduced stigma	• Coping capacities
• Supplies		and discrimination	in communities
• Training			• Economic impact

Levels of evaluation efforts

[a] Information provided by second-generation HIV surveillance systems.

WHO 04.2

HIV PREVALENCE, INCIDENCE, BEHAVIOUR AND COMMUNICATION SURVEY 2005

Funded by
The Nelson Mandela Foundation
The Swiss Agency for Development and Cooperation
Centers for Disease Control and Prevention

A collaborative research effort of
Human Sciences Research Council,
Medical Research Council &
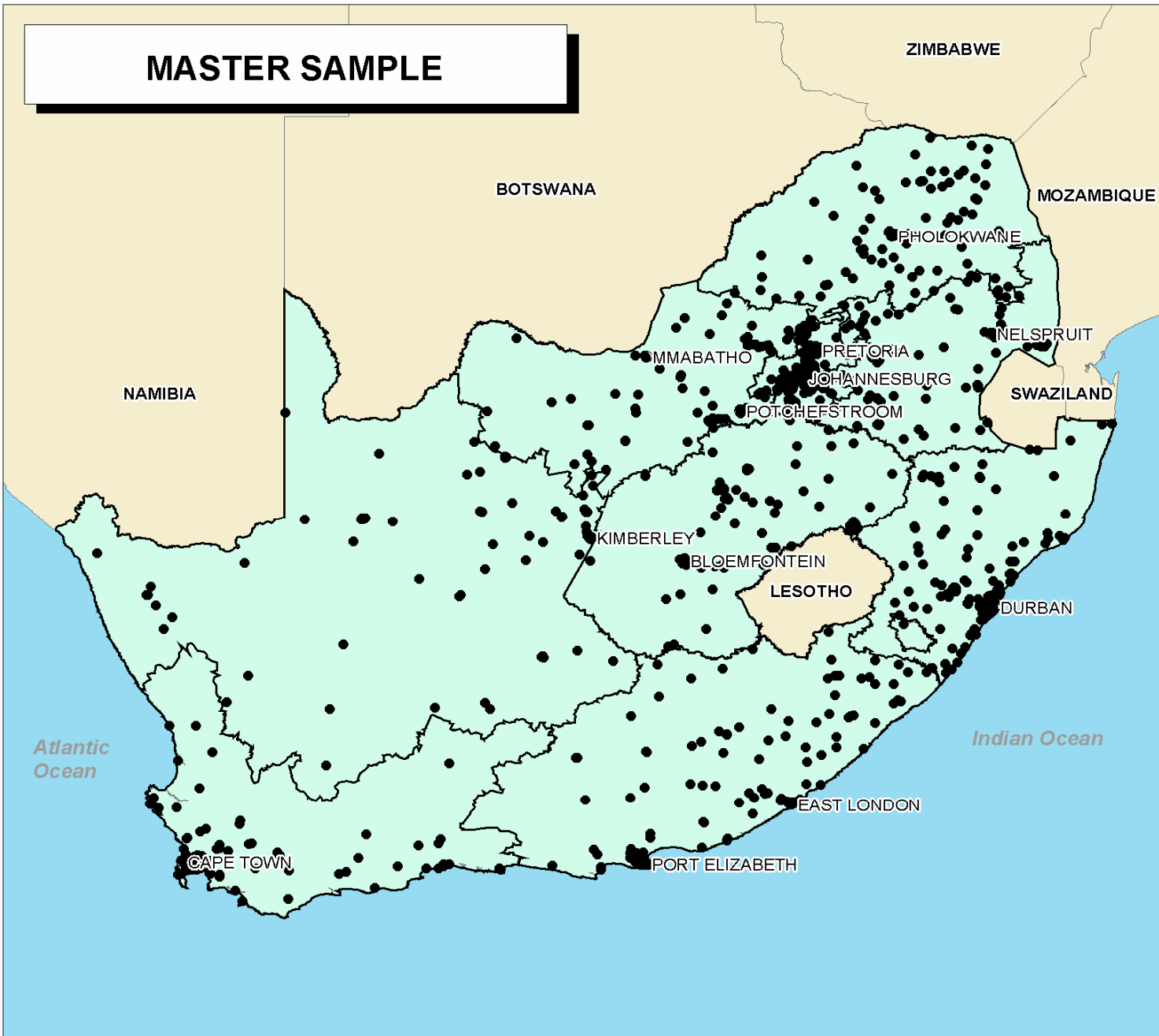Centre for AIDS Development, Research and Evaluation (CADRE)

SAHA

HSRC

Social science that makes a difference

2005 National Household Survey

- **Multi-stage cluster sampling**
- **Study population: 2 years and older**
- **Anonymous HIV testing of dried blood spot specimens**
- **HIV prevalence and HIV incidence**
- **Final sample: 23 275 interviewed, 15 851 tested for HIV**

MASTER SAMPLE

Legend

Provinces

Metropolitan centres

Master sample

ZIMBABWE

BOTSWANA

MOZAMBIQUE

NAMIBIA

PHOLOKWANE

NELSPRUIT

MMABATHO

PRETORIA

JOHANNESBURG

SWAZILAND

POTCHEFSTROOM

KIMBERLEY

BLOEMFONTEIN

LESOTHO

DURBAN

Atlantic
Ocean

Indian Ocean

EAST LONDON

CAPE TOWN

PORT ELIZABETH

N

Data Sources:

HSRC GIS Centre (2002)

Statistics South Africa

Km

0 25 50   100 150 200
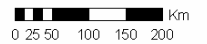
HIV Prevalence Estimates, South Africa 2005

Age Group	N	HIV (%)	95%CI
2 years and older	15 851	10.8	9.9-11.6
Children (2-14 yrs)	3 815	3.3	2.3-4.8
Youth (15 – 24 yrs)	4 120	10.3	8.7-12.0
15 – 49 years	9 24 5	16.2	14.9-17.7
=> 50 yrs	2 787	5.7	4.4-7.4

Prevalence of HIV by age and sex
South Africa 2005
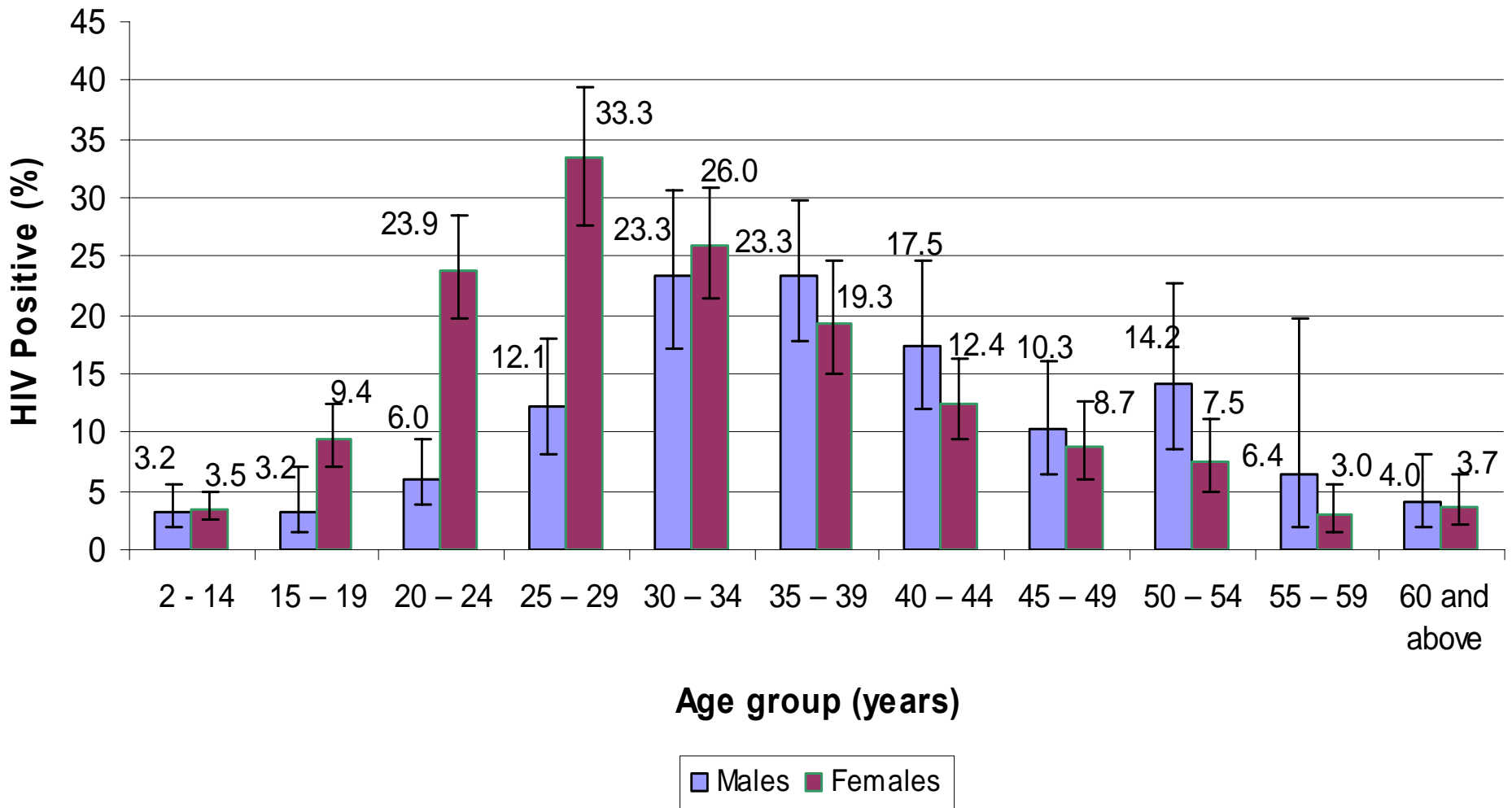
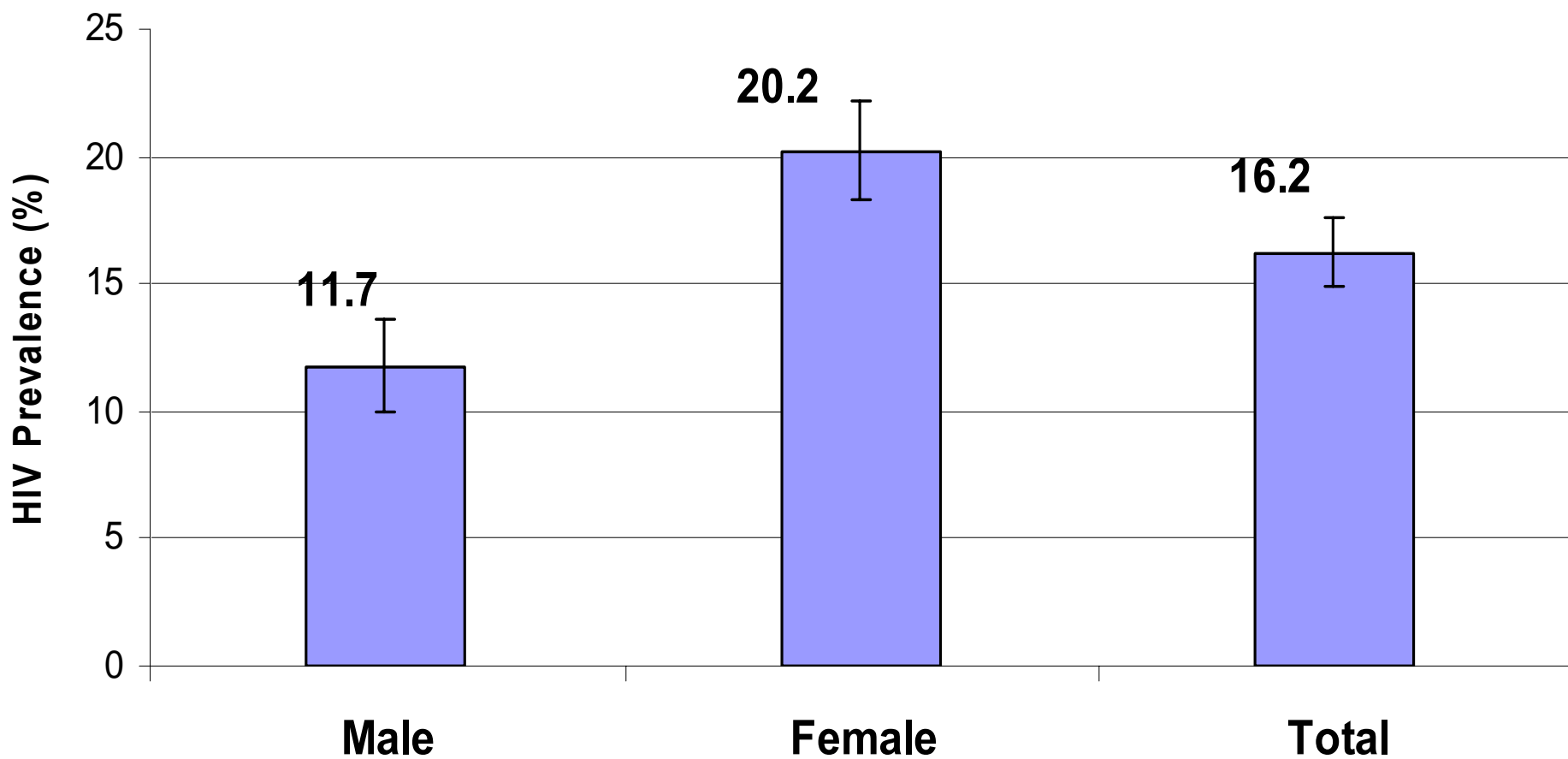HIV prevalence among youth 15 - 24 years old by sex South Africa 2005

HSRC 2005 vs. RHRU 2003

Behavioural determinants

HIV/AIDS knowledge and awareness

- **Overall basic HIV/AIDS knowledge is high**

- **There are, however, gaps in knowledge:**
  - **Uncertainty about HIV causing AIDS**
  - **Uncertainty about condoms preventing HIV infection**
  - **High degree of uncertainty that having fewer sexual partners reduces HIV risk**
  - **Uncertainty about HIV transmission from mother to child**

HIV prevalence and age mixing

- **HIV prevalence in 15-19 year olds:**

  - 29.5% for females with partner ≥5 years older
  - 17.2% for females with partner within 5 years of own age

  - 19.0% for males with partner ≥5 years older
  - 3.0% for males with partner within 5 years of own age

SAHA

HSRC

Social science that makes a difference

Perceived vulnerability to HIV infection

- **66% of respondents thought they are probably or definitely not at risk for HIV**

- **51% of the survey participants who tested positive for HIV thought they would probably or definitely not get infected with HIV**
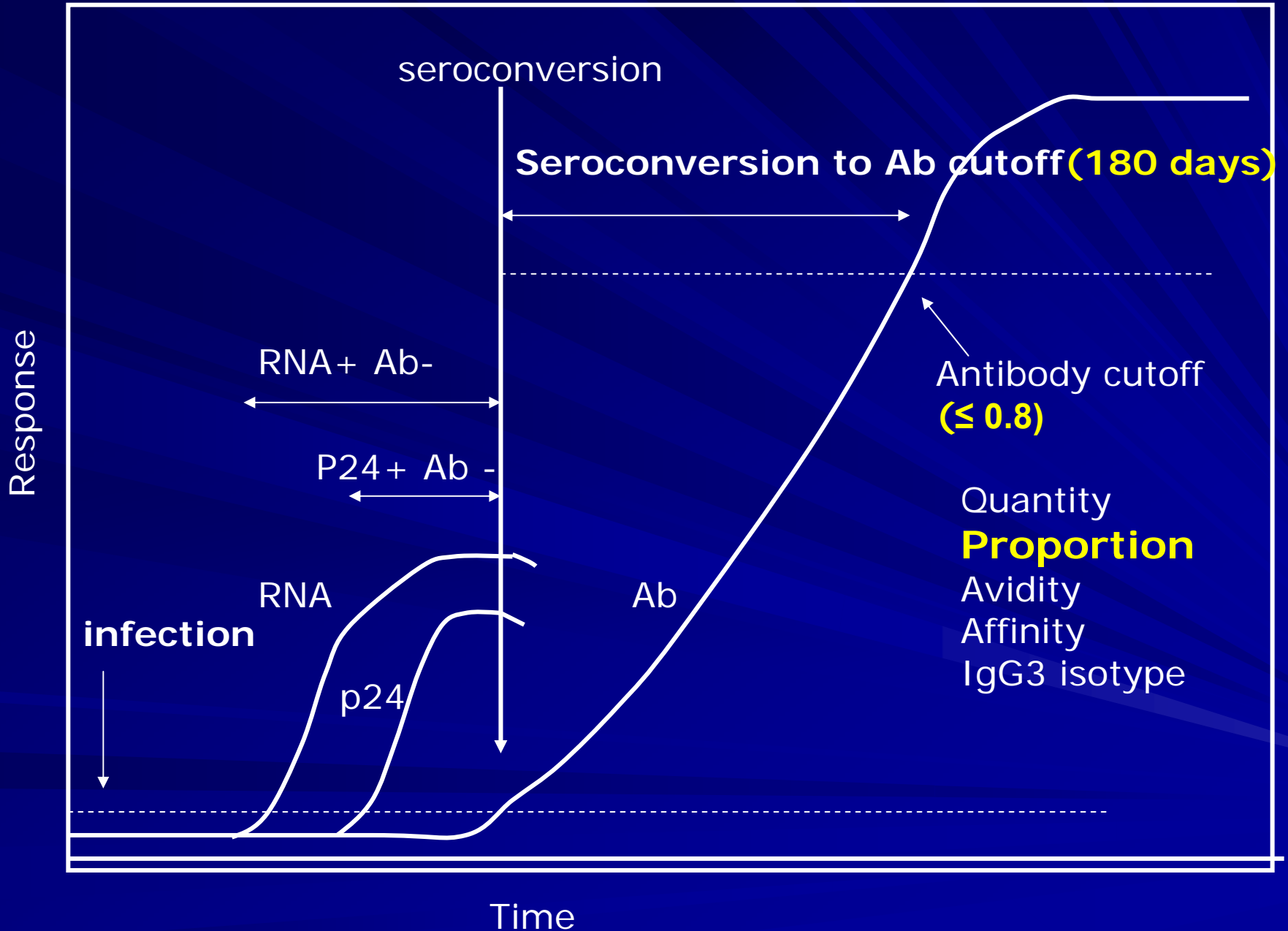
Linking HIV testing and behavioral data collection

Critical issues:

- increased cost and complexity
- non-response due to refusal of HIV testing
- potential participation bias
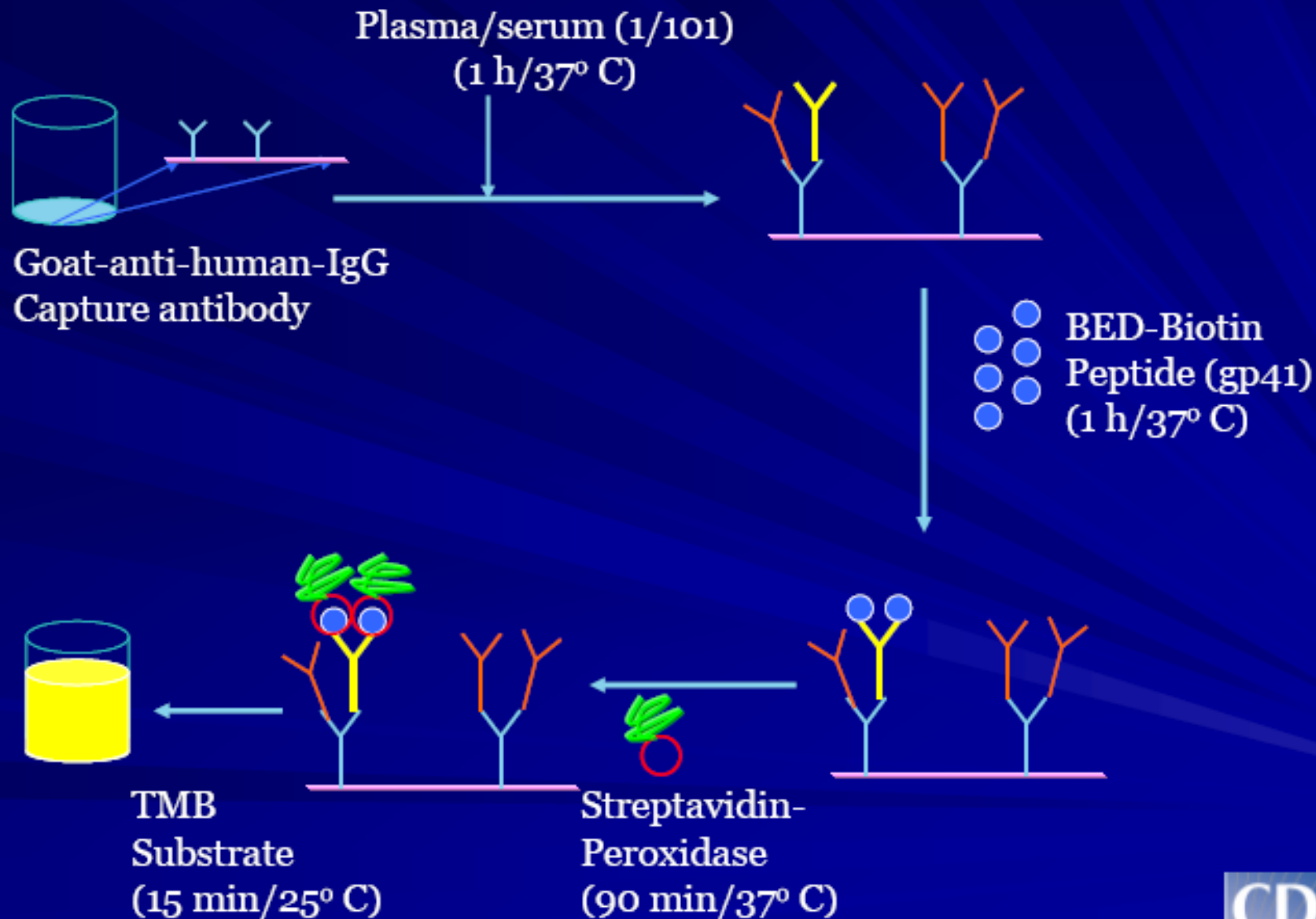- correlation of present behaviors with past infections

Measuring HIV incidence

- **Epidemiological methods**
  - **Cohort studies** *(directly observed incidence)*
  - **HIV prevalence in youngest age group (15-20)** *(as a proxy for recent infection)*
  - **Mathematical modeling** *(indirect incidence estimate)*

- **Laboratory- based methods**
  (direct incidence measure from cross-sectional surveys)

# HIV-1 BED incidence EIA (adapted from B. Parekh et al. 2002)

seroconversion

Seroconversion to Ab cutoff (180 days)

Response

RNA+ Ab-

P24+ Ab -

Antibody cutoff
(≤ 0.8)

Quantity
Proportion
Avidity
Affinity
IgG3 isotype

RNA

Ab

infection

p24

Time

Schematic of the BED-CEIA

HIV incidence % and number of new infections by age group, South Africa 2005

Age group (years)	Weighted sample (n)	HIV incidence % per year [95%CI]	Estimated number of new infections per year (n)
≥ 2	44 513 000	1.4 [1.0 - 1.8]	571 000
2-14	13 253 000	0.5 [0.0 - 1.2]	69 000
15-24	9 616 000	2.2 [1.3 - 3.1]	192 000
15-49	24 572 000	2.4 [1.7 – 3.2]	500 000

BED HIV incidence vs ASSA model (estimates for 2005)
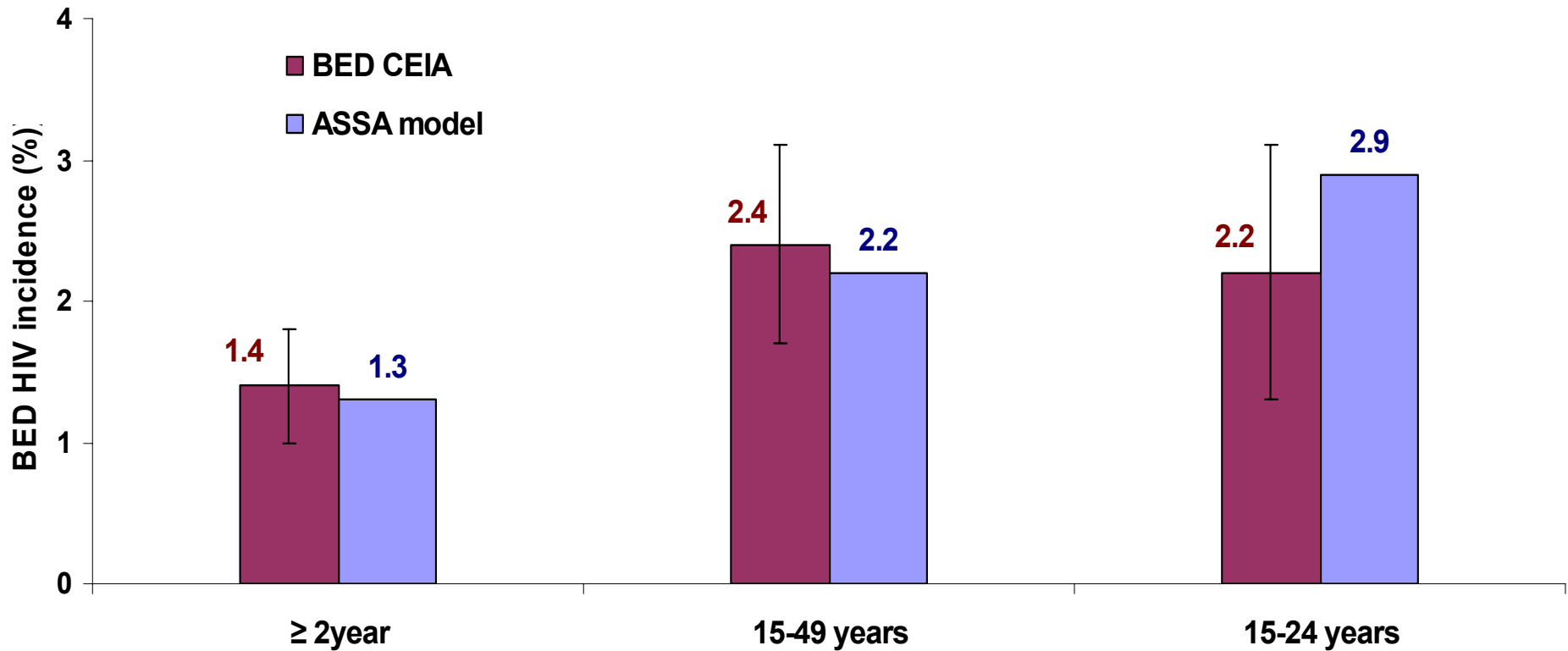
HIV prevalence and HIV incidence by age and sex, South Africa 2005
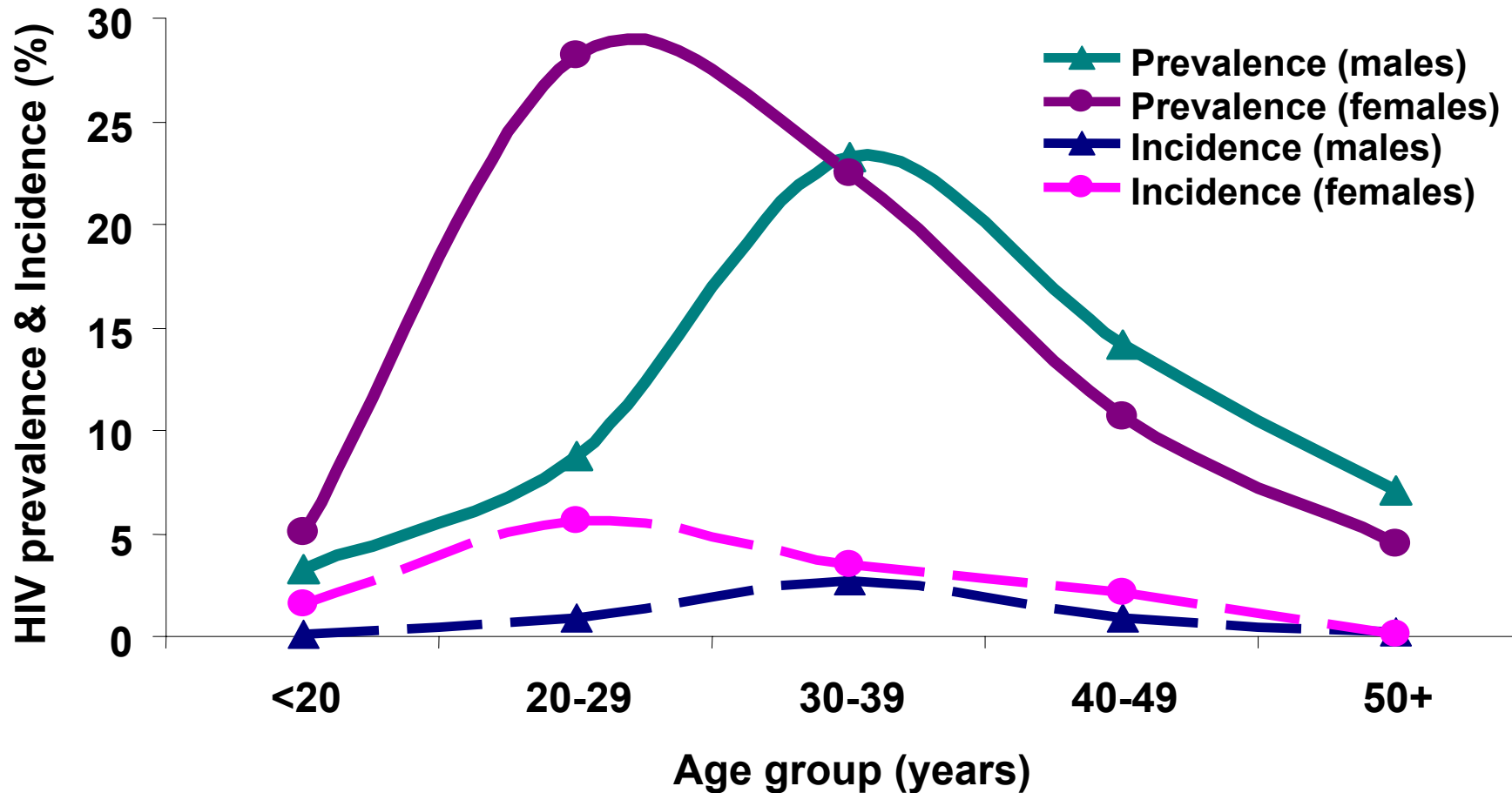
HIV incidence and behaviour HSRC 2005 (age group 15 – 49 years)

Variable	HIV incidence (% per year)
Marital status	
Single	3.0
Married	1.3
Widowed	5.8
Sexual history	
Sexually active in the past 12 months	2.4
Current pregnancy	5.2
Condom use at last sex (15-24 yrs)	
Yes	2.9
No	6.1

Conclusion

- **Incidence estimates enable a more timely analysis of the current HIV-transmission dynamics**

- **The adjusted BED HIV incidence estimates provide valid national HIV incidence estimates for South Africa**

- **Prevention campaigns did not have the desired impact, particularly among young women**