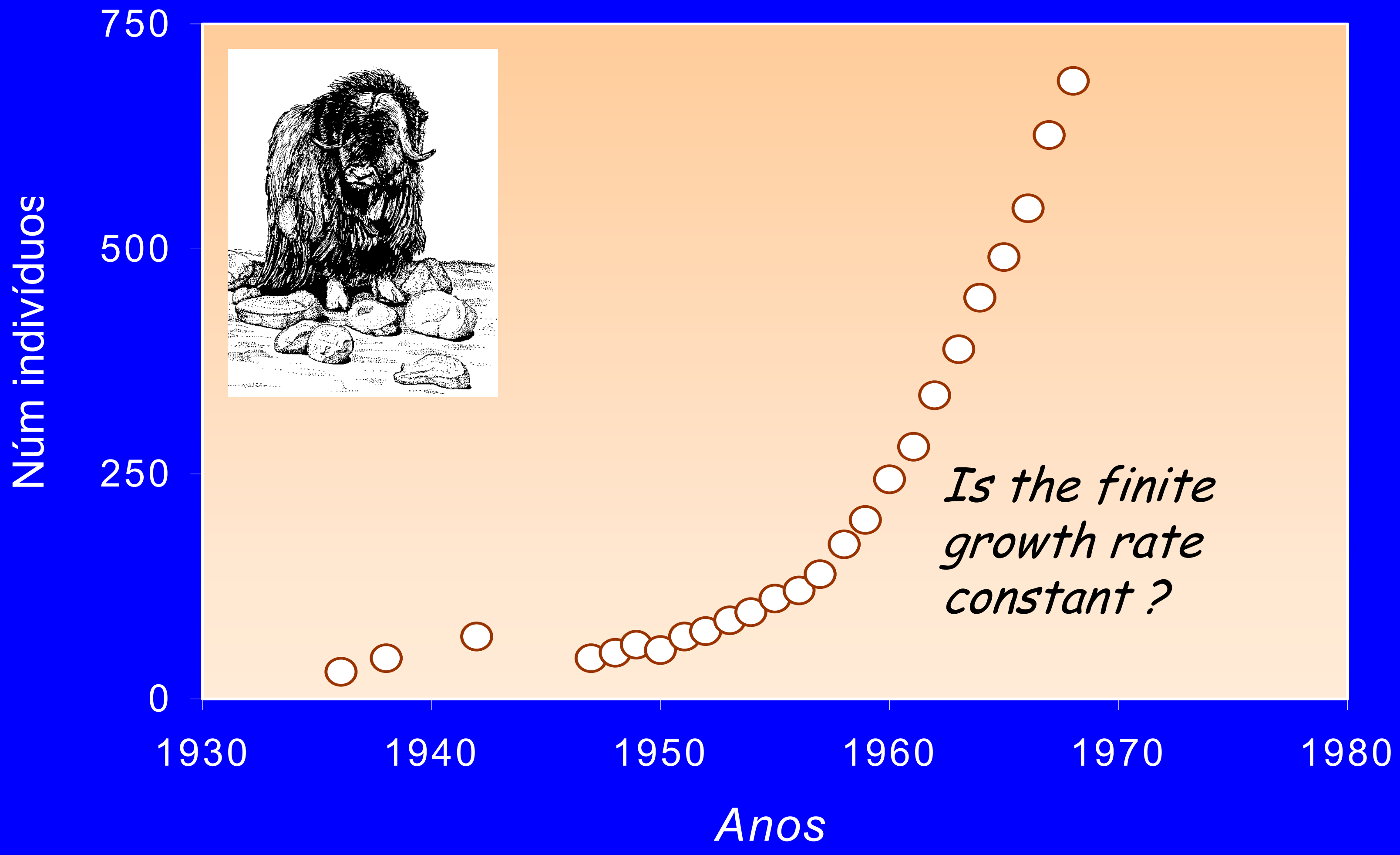
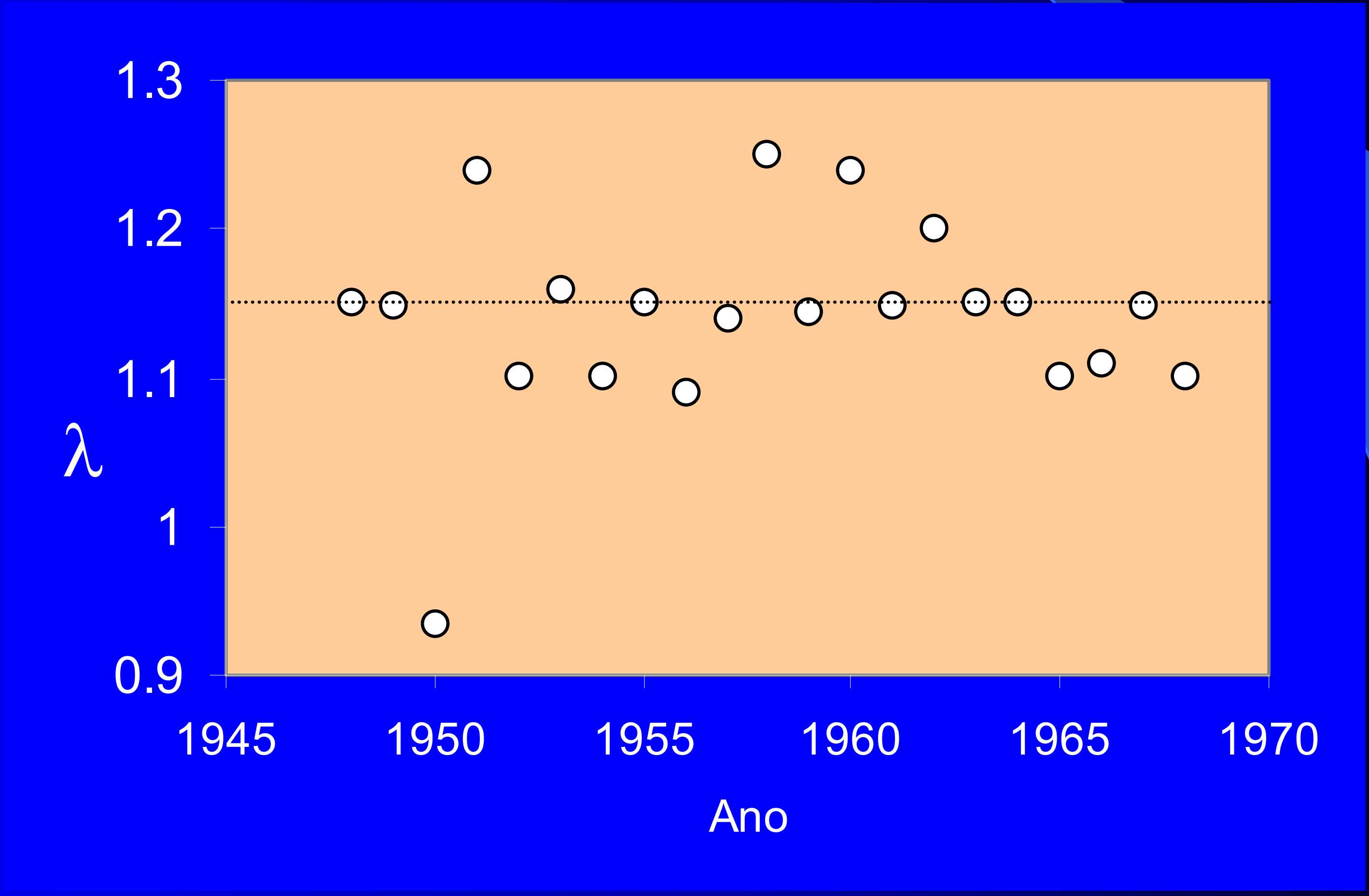
The muskox revisited



Variability in λ

Rate $\lambda = N_{t+1}/N_t$ changed every year around the mean (dashed line)



Assumptions when projecting from N_t to N_{t+1}

1. In $N_{t+1} = \lambda N_t$, we may use mean λ

   Environmental variability may be neglected

2. The population is large enough for us to ignore individual variations in breeding and survival at the individual level.

   We may neglect demographic stochasticity

Demographic stochasticity (DS)

Birth an survival take place at the individual level and are random phenomena.

It is not possible to tell exactly how many individuals are going to be born or die between t and $t+1$.

Randomness in survival and reproduction at the individual level is called:

Demographic stochasticity

When are we to worry about DS ?

If the population is very small $\rightarrow$ greater risk of extinction for merely random processes

The population may go extinct even if $r > 0$!

Exples: Colonization
Populations at the edge of the species distribution
Exploited populations (hunting and fisheries)

Deterministic and stochastic models

Deterministic

The parameters are constants (exple: λ is constant)

Same initial conditions lead to the same results

$(N_0, n) \longrightarrow (N_n)$ single results

Stochastic, random or probabilistic

Parameters take values drawn from pre-defined probability distributions

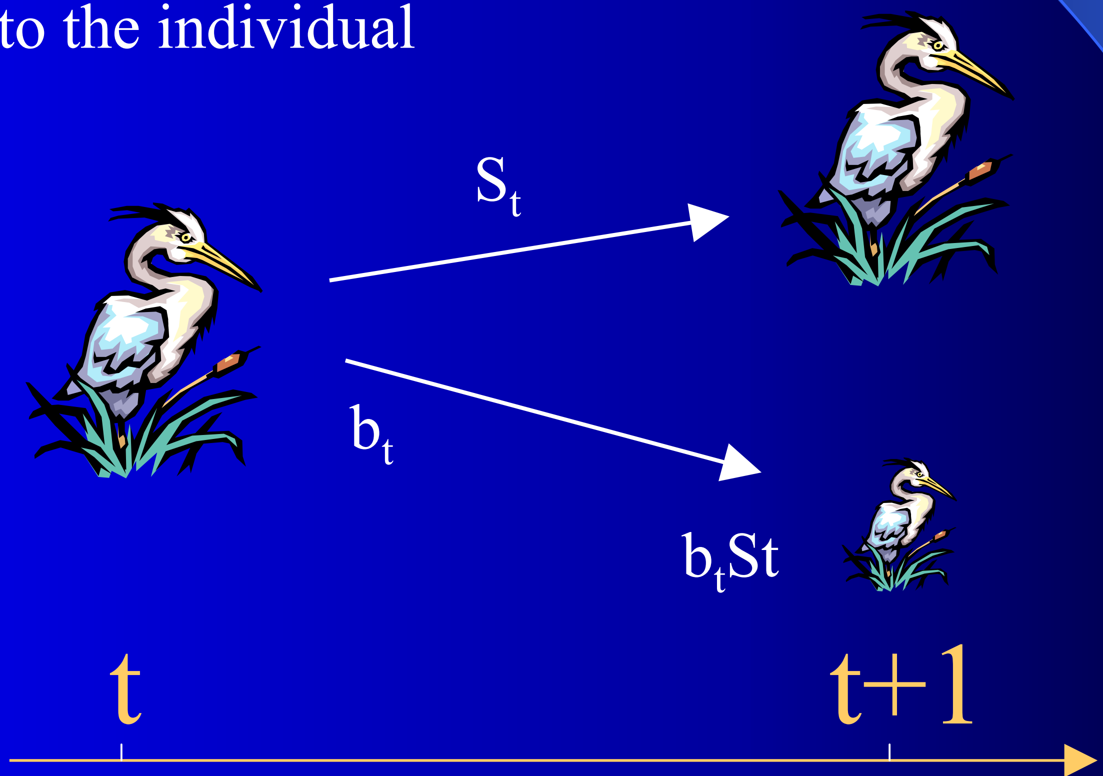
Same initial conditions do NOT lead to the same results

$(N_0, n) \longrightarrow (N'_n, N_n'', N_n''', ...)$ Distribution of results

Probabilities of surviving and number of newborns from t to t+1

$$\lambda = f(S_t, b_t)$$

Apply to the individual



Parameters for the muskox

$S_t = 0.921$ Probability of survival between t and t+1

$b_t = 0.246$ Probability of 1 newborn at t

$b_tS_t = 0.227$ Probability that the newborn is alive at t+1

Nunivak Island
31 individuals
(1936)

Simulating ES (survival)

X is a prn drawn from a standard uniform distribution

Does not survive

if X > 0.921

survives

if X < 0.921

t ***t+1***

Repeat for every animal

Simulating ES (births)

Repeat, simultaneously, for the 31 animals:

Y is a prn drawn from a standard uniform distribution

if $Y > 0.227$ → *No surviving newborn*

if $Y < 0.227$ → *1 newborn that survives*

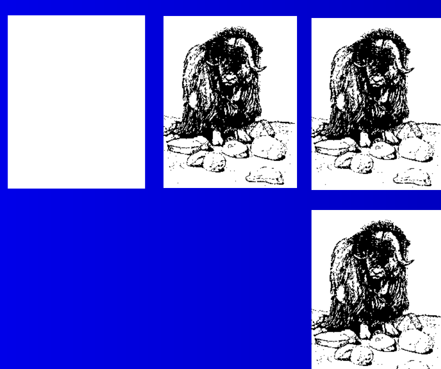
t → ***t+1***

Replicates

For 31 animals

Does this animal beget a surviving newborn ?

Does the animal survive ?



Repeat 10, 100, 1000, ... times

Each replicate yields a different number of individuals in t+1 !

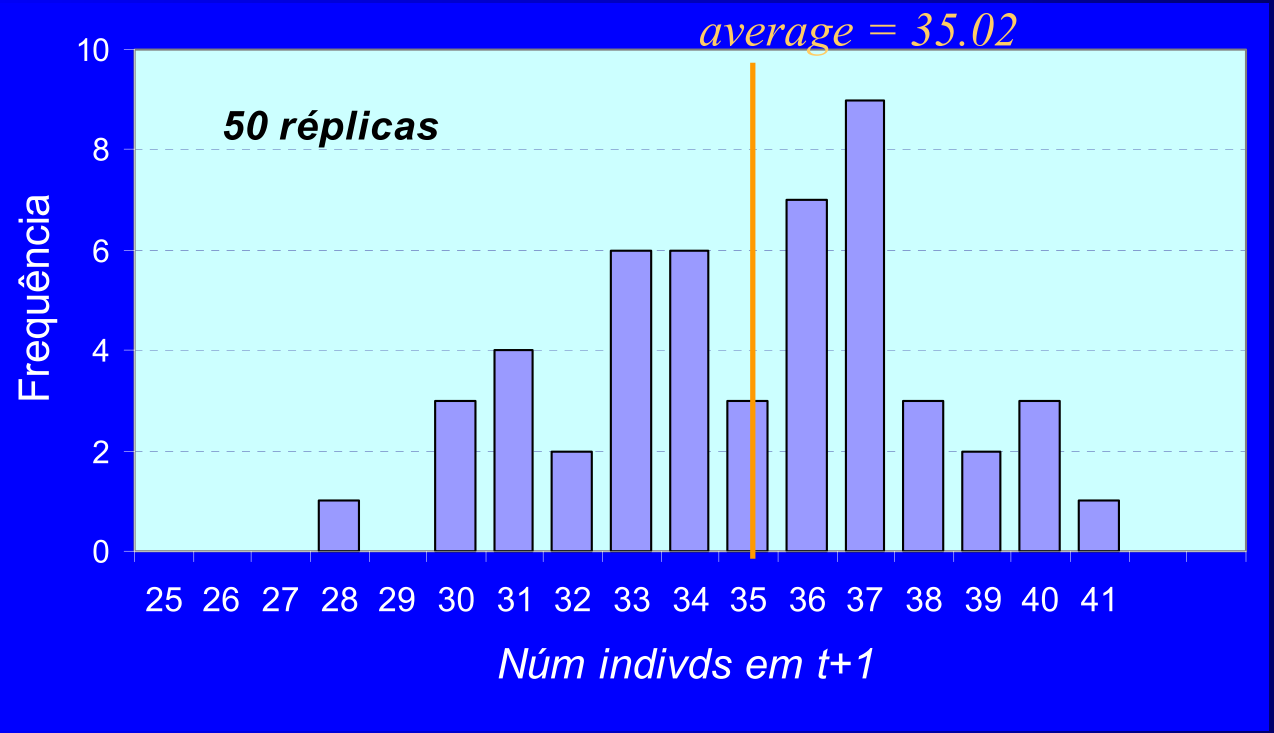
Simulations: N_t=31, 50 replicates

Deterministic model:

$N_t = 31$

$N_{t+1} = \lambda N_t = (1.148 \times 31) = 35.6$

Stochastic model



Questions addressed by the stochastic model

For example:

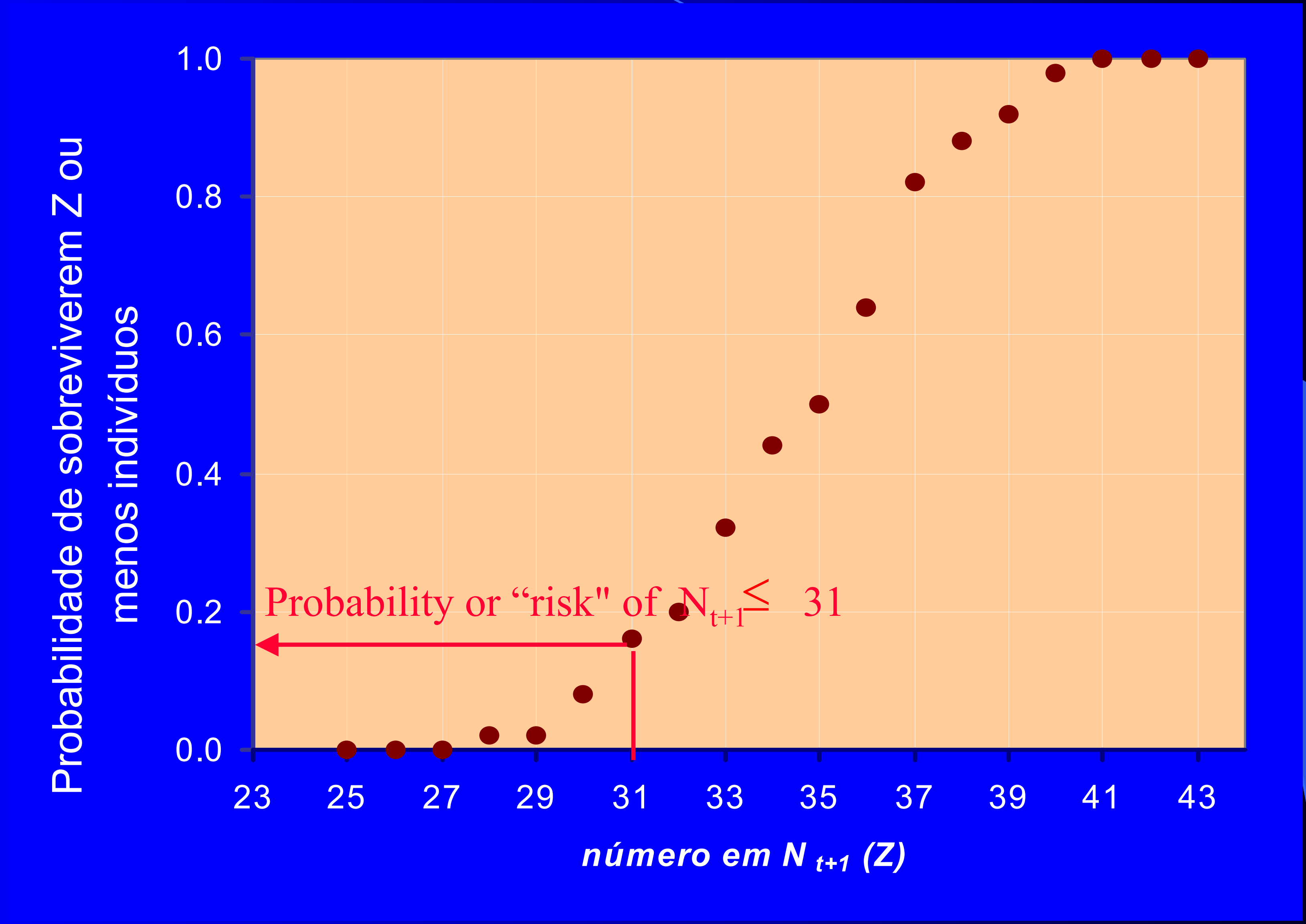
Probability of $N_{t+1} \leq$ 31 individuals ?

Probability that the population grows 10% or more ?

Probability of extinction ?

Etc.

Risk curve for period (t, t+1)



"Risk"

Risk = Probability that an adverse event takes place in a given time period

Ex^{ples}:

Population becomes smaller than x individuals within the next 3 years

A pest outbreak takes place before 2010

Population becomes extinct in 100 years

Simulating ES (births)

Repeat, for every animal:

X is number of newborns per individual in (t, t+1)
b is the ***mean*** *number of newborns per individual in (t, t+1)*
$P(X = K) \cap \text{Poisson}(b)$

X is obtained by drawing Poisson(b) prn's $X = 0, 1, 2, 3, \ldots$
(There are algorithms for this)

t

t+1