Quiz on Lesson 2

Edward L. Ionides, Aaron A. King, Qianying Lin

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Question 1. Scientifically, our conclusions should not depend on the units we choose, but we must get the details right. Suppose our data are two years of weekly aggregated case reports of a disease and we have a continuous time model solved numerically by an Euler timestep of size dt. Which of the following is a correct explanation of our options for properly implementing this in a pomp object called `po`?

(A) The measurement times, `time(po)`, should be in units of weeks, such as $1, 2, \ldots, 104$. The latent process can be modeled using arbitrary time units, say days or weeks or years. The units of dt should match the time units of the **latent** process.

(B) The measurement times, `time(po)`, should be in units of weeks, such as $1, 2, \ldots, 104$. The latent process can be modeled using arbitrary time units, say days or weeks or years. The units of dt should be in weeks (in practice, usually a fraction of a week) to match the units of the **measurement** times.

(C) The measurement times do not have to be in units of weeks. For example, we could use `time(po)`$=1/52$, $2/52, \ldots, 2$. The latent process and dt should use the same units of time as the measurement times.

(D) The measurement times do not have to be in units of weeks. For example, we could use `time(po)`$=1/52$, $2/52, \ldots, 2$. The latent process can also use arbitrary units of time, which do not necessarily match the units of the measurement times. The units of dt should match the units used for the **latent** process.

(E) The measurement times do not have to be in units of weeks. For example, we could use `time(po)`$=1/52$, $2/52, \ldots, 2$. The latent process can also use arbitrary units of time, which do not necessarily match the units of the measurement times. The units of dt should match the units used for the **measurement** times.

Solution. C. For scientific calculations, you generally have to pick an arbitrary set of units and use it consistently. In `pomp`, this means that you have to use the same units for measurement times and within the latent process. For example, if your measurement times are in days $(7, 14, \ldots)$ then rate parameters should have units day^{-1}. A latent transition with mean duration 1 week would have corresponding rate $1/7\text{day}^{-1}$.

Question 2. Suppose you obtain the following error message when you build your pomp model using Csnippets.

```
Error: error in building shared-object library from C snippets: in 'Cbuilder': compilation error:
cannot compile shared-object library '/var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_be9007eb030e47cb34264e3e779b6da9.so':
status = 1
compiler messages:
clang -mmacosx-version-min=10.13 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG
-I'/Users/ionides/Library/R/x86_64/4.1/library/pomp/include'
-I'/Users/ionides/sbied/questions'  -I/usr/local/include   -fPIC  -Wall -g -O2
-c /var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_be9007eb030e47cb34264e3e779b6da9.c
-o /var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
```

```
5324/pomp_be9007eb030e47cb34264e3e779b6da9.o
/var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_be9007eb030e47cb34264e3e779b6da9.c:39:5:
error: called object type 'int' is not a function or function pointer
    W = 0;
    ^
/var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/5
In addition: Warning message:
In system2(command = R.home("bin/R"), args = c("CMD", "SHLIB", "-c",   :
running command 'PKG_CPPFLAGS="-I'/Users/ionides/Library/R/x86_64/4.1/library/pomp/include'
-I'/Users/ionides/sbied/questions'" '/Library/Frameworks/R.framework/Resources/bin/R'
CMD SHLIB -c -o /var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_be9007eb030e47cb34264e3e779b6da9.so
/var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_be9007eb030e47cb34264e3e779b6da9.c
2>&1' had status 1
```

Which of the following is a plausible cause for this error?

(A) Using R syntax within a C function that has the same name as an R function.

(B) A parameter is missing from the **paramnames** argument to **pomp**.

(C) Indexing past the end of an array because C labels indices starting at 0.

(D) Using **beta** as a parameter name when it is a declared C function.

(E) A missing semicolon at the end of a line.

Solution. E. The error message was produced by the code below. **pomp** passes on the C compiler error message for you to inspect. Note the missing semicolon at the line end before `W=0;`.

```
sir1 <- sir()
sir2 <- pomp(sir1,statenames=c("S","I","R","cases","W"),
  paramnames=c(
    "gamma","mu","iota",
    "beta1","beta_sd","pop","rho",
    "S_0","I_0","R_0"
  ),
  rinit=Csnippet("
  double m = pop/(S_0+I_0+R_0);
  S = nearbyint(m*S_0);
  I = nearbyint(m*I_0);
  R = nearbyint(m*R_0);
  cases = 0
  W = 0;"
  )
)
```

Question 3. Suppose you obtain the following error message when you build your pomp model using Csnippets.

```
Error: error in building shared-object library from C snippets: in 'Cbuilder': compilation error:
cannot compile shared-object library '/var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_b675d99e691eda865610f570058ea3be.so': status = 1
compiler messages:
```

```
clang -mmacosx-version-min=10.13 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG
-I'/Users/ionides/Library/R/x86_64/4.1/library/pomp/include' -I'/Users/ionides/sbied/questions'
-I/usr/local/include   -fPIC  -Wall -g -O2
-c /var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_b675d99e691eda865610f570058ea3be.c
-o /var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_b675d99e691eda865610f570058ea3be.o
/var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_b675d99e691eda865610f570058ea3be.c:33:16:
error: use of undeclared identifier 'pop'; did you mean 'pow'?
    double m = pop/(S_0+I_0+R_0);
               ^~~
               pow
/Applications/
In addition: Warning message:
In system2(command = R.home("bin/R"), args = c("CMD", "SHLIB", "-c",  :
  running command 'PKG_CPPFLAGS="-I'/Users/ionides/Library/R/x86_64/4.1/library/pomp/include'
-I'/Users/ionides/sbied/questions'" '/Library/Frameworks/R.framework/Resources/bin/R' CMD SHLIB
-c -o /var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_b675d99e691eda865610f570058ea3be.so
/var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_b675d99e691eda865610f570058ea3be.c 2>&1' had status 1
```

Which of the following is a plausible cause for this error?

(A) Using R syntax within a C function that has the same name as an R function.

(B) A parameter is missing from the **paramnames** argument to **pomp**.

(C) Indexing past the end of an array because C labels indices starting at 0.

(D) Using **beta** as a parameter name when it is a declared C function.

(E) A missing semicolon at the end of a line.

Solution. B. The code generating this error is below. Here, **pop** is intended to be passed as a parameter, but it is missing from the **paramnames** argument. It could alternatively be defined as a global variable using the **globals** argument to **pomp**.

```
sir3 <- pomp(sir1,statenames=c("S","I","R","cases","W"),
  paramnames=c(
    "gamma","mu","iota",
    "beta1","beta_sd","rho",
    "S_0","I_0","R_0"
  ),
  rinit=Csnippet("
  double m = pop/(S_0+I_0+R_0);
  S = nearbyint(m*S_0);
  I = nearbyint(m*I_0);
  R = nearbyint(m*R_0);
  cases = 0
  W = 0;"
  )
)
```

Question 4. Suppose you obtain the following error message when you build your pomp model using Csnippets.

```
Error: error in building shared-object library from C snippets: in 'Cbuilder': compilation error:
cannot compile shared-object library '/var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_77886fb66d95b4b9904440d86a4425b3.so': status = 1
compiler messages:
clang -mmacosx-version-min=10.13 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG
-I'/Users/ionides/Library/R/x86_64/4.1/library/pomp/include'
-I'/Users/ionides/sbied/questions'  -I/usr/local/include   -fPIC  -Wall -g -O2
-c /var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_77886fb66d95b4b9904440d86a4425b3.c
-o /var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_77886fb66d95b4b9904440d86a4425b3.o
/var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_77886fb66d95b4b9904440d86a4425b3.c:39:36:
error: too many arguments to function call, expected 2, have 3
     rep = nearbyint(rnorm(1,mean,sd));
                     ~~~~~        ^~
/Librar
In addition: Warning message:
In system2(command = R.home("bin/R"), args = c("CMD", "SHLIB", "-c",   :
running command 'PKG_CPPFLAGS="-I'/Users/ionides/Library/R/x86_64/4.1/library/pomp/include'
-I'/Users/ionides/sbied/questions'" '/Library/Frameworks/R.framework/Resources/bin/R'
CMD SHLIB -c -o /var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_77886fb66d95b4b9904440d86a4425b3.so
/var/folders/fv/pt62sh2d6_gf9fp3t7b466vr0000gr/T//RtmpD16GmG/
5324/pomp_77886fb66d95b4b9904440d86a4425b3.c 2>&1' had status 1
```

Which of the following is a plausible cause for this error?

(A) Using R syntax within a C function that has the same name as an R function.

(B) A parameter is missing from the `paramnames` argument to `pomp`.

(C) Indexing past the end of an array because C labels indices starting at 0.

(D) Using `beta` as a parameter name when it is a declared C function.

(E) A missing semicolon at the end of a line.

Solution. A. The code producing the error is below. Within Csnippets, the C versions of R distribution functions are available but they have slightly different syntax from their more familiar R cousins.

```
sir4 <- pomp(sir1,statenames=c("S","I","R","cases","W"),
  paramnames=c(
    "gamma","mu","iota",
    "beta1","beta_sd","pop","rho",
    "S_0","I_0","R_0"
  ),
  rmeasure=Csnippet("
    double mean, sd;
    double rep;
    mean = cases*rho;
    sd = sqrt(cases*rho*(1-rho));
    rep = nearbyint(rnorm(1,mean,sd));
```

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```
    reports = (rep > 0) ? rep : 0;"
  )
)
```

Question 5. Let V_n be a Markov process and let $W_n = h(V_n)$ for some function h. Which of the following statements are true?

i) W_n is a Markov process for all choices of h.

ii) W_n is a Markov process for some choices of h.

iii) W_n is not a Markov process for any choice of h.

iv) If $V_n = (X_n, Y_n)$ where X_n and Y_n are a POMP model, and $h(X_n, Y_n) = X_n$ then W_n is a Markov process.

v) If $V_n = (X_n, Y_n)$ where X_n and Y_n are a POMP model, and $h(X_n, Y_n) = Y_n$ then W_n is a Markov process.

(A) i,iv,v

(B) ii,iv

(C) ii,v

(D) iii

(E) None of the above

Solution. B.