Create a generic subnetwork from Recon 3D

Author(s): Ines Thiele, Ronan M. T. Fleming, Systems Biochemistry Group, LCSB, University of Luxembourg.

Reviewer(s): Almut Heinken, University of Luxembourg.

In this tutorial, we show how to create a generic subnetwork from Recon 3D that can still perform all metabolic test functions as well as has physiologically defined ATP yield from defined carbon sources. The resulting model does not contain a specified list of reactions, except if they are still needed for the aforementioned tasks, and that is flux consistent.

EQUIPMENT SETUP

If necessary, initialize the cobra toolbox:

```
initCobraToolbox
```

```
                                                                |
     _____   _____   _____   _____      _____                   |
    /  ___| /  _  \ |  _  \ |  _  \    /  ___ \                  |   COnstraint-Based Reconstruction and Analysis
    | |     | | | | | |_| | | |_| |    | |___| |                 |   The COBRA Toolbox - 2017
    | |     | | | | |  _  { |  _  /    |  ___  |                 |
    | |___  | |_| | | |_| | | | \ \    | |   | |                 |   Documentation:
    \_____| \_____/ |_____/ |_|  \_\   |_|   |_|                 |   http://opencobra.github.io/cobratoolbox
                                                                |
```

```
> Checking if git is installed ...  Done.
> Checking if the repository is tracked using git ...  Done.
> Checking if curl is installed ...  Done.
> Checking if remote can be reached ...  Done.
> Initializing and updating submodules ... Done.
> Adding all the files of The COBRA Toolbox ...  Done.
> Define CB map output... set to svg.
> Retrieving models ...   Done.
> TranslateSBML is installed and working properly.
> Configuring solver environment variables ...
  - [*---] ILOG_CPLEX_PATH: C:\Program Files\IBM\ILOG\CPLEX_Studio1263\cplex\matlab\x64_win64
  - [----] GUROBI_PATH :  --> set this path manually after installing the solver ( see instructions )
  - [*---] TOMLAB_PATH: C:\tomlab\
  - [----] MOSEK_PATH :  --> set this path manually after installing the solver ( see instructions )
  Done.
> Checking available solvers and solver interfaces ... Done.
> Setting default solvers ... Done.
> Saving the MATLAB path ... Done.
  - The MATLAB path was saved in the default location.

> Summary of available solvers and solver interfaces

    Support           LP   MILP     QP   MIQP    NLP
-------------------------------------------------------------------
cplex_direct  full              0      0      0      0      -
dqqMinos      full              0      -      -      -      -
glpk          full              1      1      -      -      -
gurobi        full              1      1      1      1      -
ibm_cplex     full              0      0      0      -      -
matlab        full              1      -      -      -      1
mosek         full              0      0      0      -      -
pdco          full              1      -      1      -      -
quadMinos     full              0      -      -      -      0
tomlab_cplex  full              1      1      1      1      -
```

```
qpng          experimental       -      -      1      -      -
tomlab_snopt  experimental       -      -      -      -      1
gurobi_mex    legacy             0      0      0      0      -
lindo_old     legacy             0      -      -      -      -
lindo_legacy  legacy             0      -      -      -      -
lp_solve      legacy             1      -      -      -      -
opti          legacy             0      0      0      0      0
-------------------------------------------------------------------
Total         -                  6      3      4      2      2

+ Legend: - = not applicable, 0 = solver not compatible or not installed, 1 = solver installed.


> You can solve LP problems using: 'glpk' - 'gurobi' - 'matlab' - 'pdco' - 'tomlab_cplex' - 'lp_solve'
> You can solve MILP problems using: 'glpk' - 'gurobi' - 'tomlab_cplex'
> You can solve QP problems using: 'gurobi' - 'pdco' - 'tomlab_cplex' - 'qpng'
> You can solve MIQP problems using: 'gurobi' - 'tomlab_cplex'
> You can solve NLP problems using: 'matlab' - 'tomlab_snopt'

> Checking for available updates ...
--> You cannot update your fork using updateCobraToolbox(). [940ff8 @ develop].
    Please use the MATLAB.devTools (https://github.com/opencobra/MATLAB.devTools).
```

For solving linear programming problems in FBA analysis, certain solvers are required:

```
% changeCobraSolver ('glpk', 'all', 1);
changeCobraSolver ('tomlab_cplex', 'all', 1);
```

```
> Tomlab interface added to MATLAB path.
> Solver for LPproblems has been set to tomlab_cplex.

> Tomlab interface added to MATLAB path.
> Solver for MILPproblems has been set to tomlab_cplex.

> Tomlab interface added to MATLAB path.
> Solver for QPproblems has been set to tomlab_cplex.

> Tomlab interface added to MATLAB path.
> Solver for MIQPproblems has been set to tomlab_cplex.
> Solver tomlab_cplex not supported for problems of type NLP. Currently used: matlab
```

This tutorial can be run with `'glpk'` package as linear programming solver, which does not require additional instalation and configuration. However, for the analysis of large models, such as Recon 3, it is not recommended to use `'glpk'` but rather industrial strenght solvers, such as the `'gurobi'` package. For detail information, refer to the solver instalation guide: https://github.com/opencobra/cobratoolbox/blob/master/docs/source/installation/solvers.md

```
warning off MATLAB:subscripting:noSubscriptsSpecified
```

PROCEDURE

Before proceeding with the simulations, the path for the model needs to be set up. In this tutorial, the used model is the generic model of human metabolism, Recon 3 [1]. If Recon 3 is not available, please use Recon 2.

```
if exist('2017_04_28_Recon3dForCurrentDistribution.mat','file')==2
    filename = '2017_04_28_Recon3dForCurrentDistribution.mat';
    load(filename);
    model=modelRecon3model;
    clear modelRecon3model;
```

```
    model.csense(1:size(model.S,1),1)='E';
else
    filename2='Recon2.0model.mat';
    if exist('Recon2.0model.mat','file')==2
        load(filename2);
        model=Recon2model;
        clear Recon2model;
        model.csense(1:size(model.S,1),1)='E';
    end
end
```

Set the lower bounds on all biomass reactions and sink/demand reactions to zero.

```
model.lb(find(ismember(model.rxns,'biomass_reaction')))=0;
model.lb(find(ismember(model.rxns,'biomass_maintenance_noTrTr')))=0;
model.lb(find(ismember(model.rxns,'biomass_maintenance')))=0;
DMs = (strmatch('DM_',model.rxns));
model.lb(DMs) = 0;
Sinks = (strmatch('sink_',model.rxns));
model.lb(Sinks) = 0;
model.ub(Sinks) = 1000;
```

Test, which model reactions are needed to ensure that all carbon sources result in a physiologically relevant ATP yield. Note that this function uses sparseFBA, i.e., alternative solutions may exist but are not considered here.

```
[Table_csourcesOri, TestedRxnsC, Perc] = testATPYieldFromCsources(model);
```

```
Warning: Reaction with the same name already exists in the model, updating the reaction
DM_atp_c_ h2o[c] + atp[c]  -> h[c] + adp[c] + pi[c]
```

Test, which model reactions are needed to ensure that all metabolic functions can have a non-zero flux. Note that this function uses sparseFBA, i.e., alternative solutions may exist but are not considered here.

```
[TestSolutionOri,TestSolutionNameClosedSinks, TestedRxnsClosedSinks, PercClosedSinks] = Test4H
```

```
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_gly(c) gly(c)  <=>
sink_co2(c) co2(c)  ->
sink_nh4(c) nh4(c)  ->
sink_12ppd-S(c) 12ppd-S(c)  <=>
sink_mthgxl(c) mthgxl(c)  ->
sink_12ppd-S(c) 12ppd-S(c)  <=>
sink_pyr(c) pyr(c)  ->
sink_3pg(c) 3pg(c)  <=>
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_gly(c) gly(c)  ->
sink_3pg(c) 3pg(c)  <=>
sink_ser-L(c) ser-L(c)  ->
sink_4abut(c) 4abut(c)  <=>
sink_succ(m) succ(m)  ->
sink_4hpro-LT(m) 4hpro-LT(m)  <=>
sink_glx(m) glx(m)  ->
sink_5aop(c) 5aop(c)  <=>
sink_pheme(c) pheme(c)  ->
sink_aact(c) aact(c)  <=>
sink_mthgxl(c) mthgxl(c)  ->
sink_acac(m) acac(m)  <=>
sink_acetone(m) acetone(m)  ->
```

```
sink_acac(m) acac(m)  <=>
sink_bhb(m) bhb(m)  ->
sink_acald(c) acald(c)  <=>
sink_ac(c) ac(c)  ->
sink_accoa(c) accoa(c)  <=>
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_pmtcoa(c) pmtcoa(c)  ->
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_pmtcoa(c) pmtcoa(c)  <=>
sink_malcoa(m) malcoa(m)  ->
sink_acetone(c) acetone(c)  <=>
sink_mthgxl(c) mthgxl(c)  ->
sink_acgal(c) acgal(c)  <=>
sink_udpacgal(c) udpacgal(c)  ->
sink_acgam(c) acgam(c)  <=>
sink_cmpacna(c) cmpacna(c)  ->
sink_acorn(c) acorn(c)  <=>
sink_orn(c) orn(c)  ->
sink_adrnl(c) adrnl(c)  <=>
sink_34dhoxpeg(c) 34dhoxpeg(c)  ->
sink_akg(m) akg(m)  <=>
sink_oaa(m) oaa(m)  ->
sink_akg(m) akg(m)  <=>
sink_glu-L(m) glu-L(m)  ->
sink_akg(m) akg(m)  <=>
sink_ala-B(c) ala-B(c)  <=>
sink_msa(m) msa(m)  ->
sink_ala-D(c) ala-D(c)  <=>
sink_pyr(c) pyr(c)  ->
sink_ala-L(c) ala-L(c)  <=>
sink_ala-D(c) ala-D(c)  ->
sink_ala-L(c) ala-L(c)  <=>
sink_pyr(c) pyr(c)  ->
sink_arachd(c) arachd(c)  <=>
sink_malcoa(m) malcoa(m)  ->
sink_arachd(r) arachd(r)  <=>
sink_txa2(r) txa2(r)  ->
sink_arg-L(c) arg-L(c)  <=>
sink_creat(c) creat(c)  ->
sink_arg-L(c) arg-L(c)  <=>
sink_glu-L(m) glu-L(m)  ->
sink_arg-L(c) arg-L(c)  <=>
sink_no(c) no(c)  ->
sink_arg-L(c) arg-L(c)  <=>
sink_pcreat(c) pcreat(c)  ->
sink_ascb-L(c) ascb-L(c)  <=>
Warning: Metabolite eryth(c) not in model - added to the model
sink_eryth(c) eryth(c)  ->
sink_ascb-L(c) ascb-L(c)  <=>
Warning: Metabolite lyxnt(c) not in model - added to the model
sink_lyxnt(c) lyxnt(c)  ->
sink_ascb-L(c) ascb-L(c)  <=>
sink_thrnt(c) thrnt(c)  ->
sink_ascb-L(c) ascb-L(c)  <=>
Warning: Metabolite xylnt(c) not in model - added to the model
sink_xylnt(c) xylnt(c)  ->
sink_asn-L(c) asn-L(c)  <=>
sink_oaa(c) oaa(c)  ->
sink_asp-L(c) asp-L(c)  <=>
sink_hco3(c) hco3(c)  <=>
sink_arg-L(c) arg-L(c)  ->
sink_asp-L(c) asp-L(c)  <=>
sink_ala-B(c) ala-B(c)  ->
sink_asp-L(c) asp-L(c)  <=>
sink_asn-L(c) asn-L(c)  ->
```

```
sink_asp-L(c) asp-L(c)  <=>
sink_argsuc(c) argsuc(c)  ->
sink_argsuc(c) argsuc(c)  <=>
sink_fum(c) fum(c)  ->
sink_asp-L(c) asp-L(c)  <=>
sink_dcamp(c) dcamp(c)  ->
sink_dcamp(c) dcamp(c)  <=>
sink_fum(c) fum(c)  ->
sink_dcamp(c) dcamp(c)  <=>
sink_fum(c) fum(c)  ->
sink_asp-L(c) asp-L(c)  <=>
sink_oaa(c) oaa(c)  ->
sink_carn(c) carn(c)  <=>
sink_ala-B(c) ala-B(c)  ->
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_chol(c) chol(c)  <=>
sink_dag_hs(c) dag_hs(c)  <=>
sink_pe_hs(c) pe_hs(c)  ->
sink_chol(m) chol(m)  <=>
sink_glyb(m) glyb(m)  ->
sink_glyb(m) glyb(m)  <=>
sink_gly(m) gly(m)  ->
sink_coke(r) coke(r)  <=>
Warning: Metabolite pecgoncoa(r) not in model - added to the model
sink_pecgoncoa(r) pecgoncoa(r)  ->
sink_core2(g) core2(g)  <=>
sink_ksii_core2(g) ksii_core2(g)  ->
sink_core4(g) core4(g)  <=>
sink_ksii_core4(g) ksii_core4(g)  ->
sink_cspg_a(l) cspg_a(l)  <=>
sink_gal(l) gal(l)  ->
sink_glcur(l) glcur(l)  ->
sink_xyl-D(l) xyl-D(l)  ->
sink_cspg_b(l) cspg_b(l)  <=>
sink_gal(l) gal(l)  ->
sink_glcur(l) glcur(l)  ->
sink_xyl-D(l) xyl-D(l)  ->
sink_cspg_c(l) cspg_c(l)  <=>
sink_gal(l) gal(l)  ->
sink_glcur(l) glcur(l)  ->
sink_xyl-D(l) xyl-D(l)  ->
sink_cspg_d(l) cspg_d(l)  <=>
sink_gal(l) gal(l)  ->
sink_glcur(l) glcur(l)  ->
sink_xyl-D(l) xyl-D(l)  ->
sink_cspg_e(l) cspg_e(l)  <=>
sink_gal(l) gal(l)  ->
sink_glcur(l) glcur(l)  ->
sink_xyl-D(l) xyl-D(l)  ->
sink_cys-L(c) cys-L(c)  <=>
sink_glu-L(c) glu-L(c)  <=>
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_gly(c) gly(c)  <=>
sink_gthrd(c) gthrd(c)  ->
sink_cys-L(c) cys-L(c)  <=>
sink_3sala(c) 3sala(c)  ->
sink_3sala(c) 3sala(c)  <=>
sink_so4(c) so4(c)  ->
sink_cys-L(c) cys-L(c)  <=>
sink_hyptaur(c) hyptaur(c)  ->
sink_Lcystin(c) Lcystin(c)  <=>
sink_cys-L(c) cys-L(c)  ->
sink_dhap(c) dhap(c)  <=>
sink_mthgxl(c) mthgxl(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
```

```
sink_dmpp(c) dmpp(c)  <=>
Warning: Metabolite ggdp(c) not in model - added to the model
sink_ggdp(c) ggdp(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
Warning: Metabolite dna(n) not in model - added to the model
sink_dna(n) dna(n)  <=>
Warning: Metabolite dna5mtc(n) not in model - added to the model
sink_dna5mtc(n) dna5mtc(n)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_dolichol_L(c) dolichol_L(c)  <=>
Warning: Metabolite dolmanp_L(r) not in model - added to the model
sink_dolmanp_L(r) dolmanp_L(r)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_dolichol_L(c) dolichol_L(c)  <=>
Warning: Metabolite g3m8mpdol_L(r) not in model - added to the model
sink_g3m8mpdol_L(r) g3m8mpdol_L(r)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_dolichol_U(c) dolichol_U(c)  <=>
sink_dolmanp_U(r) dolmanp_U(r)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_dolichol_U(c) dolichol_U(c)  <=>
Warning: Metabolite g3m8mpdol_U(r) not in model - added to the model
sink_g3m8mpdol_U(r) g3m8mpdol_U(r)  ->
sink_dopa(c) dopa(c)  <=>
sink_homoval(c) homoval(c)  ->
sink_etoh(c) etoh(c)  <=>
sink_acald(c) acald(c)  ->
sink_f6p(c) f6p(c)  <=>
sink_g3p(c) g3p(c)  <=>
sink_r5p(c) r5p(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_frdp(c) frdp(c)  <=>
sink_dolichol_L(r) dolichol_L(r)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
```

```
sink_frdp(c) frdp(c)  <=>
sink_dolichol_U(r) dolichol_U(r)  ->
sink_ade(c) ade(c)  <=>
sink_amp(c) amp(c)  ->
sink_adn(c) adn(c)  <=>
sink_urate(x) urate(x)  ->
sink_adp(c) adp(c)  <=>
sink_datp(n) datp(n)  ->
sink_cdp(c) cdp(c)  <=>
sink_dctp(n) dctp(n)  ->
sink_cmp(c) cmp(c)  <=>
sink_cytd(c) cytd(c)  ->
sink_cytd(c) cytd(c)  <=>
sink_ala-B(c) ala-B(c)  ->
sink_dcmp(c) dcmp(c)  <=>
sink_ala-B(c) ala-B(c)  ->
sink_gdp(c) gdp(c)  <=>
sink_dgtp(n) dgtp(n)  ->
sink_gln-L(c) gln-L(c)  <=>
```

```
sink_hco3(c) hco3(c)  <=>
sink_ump(c) ump(c)  ->
sink_gsn(c) gsn(c)  <=>
sink_urate(x) urate(x)  ->
sink_gua(c) gua(c)  <=>
sink_gmp(c) gmp(c)  ->
sink_hxan(c) hxan(c)  <=>
sink_imp(c) imp(c)  ->
sink_imp(c) imp(c)  <=>
sink_atp(c) atp(c)  ->
sink_imp(c) imp(c)  <=>
sink_gtp(c) gtp(c)  ->
sink_imp(c) imp(c)  <=>
sink_urate(x) urate(x)  ->
sink_prpp(c) prpp(c)  <=>
sink_imp(c) imp(c)  ->
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_pydx(c) pydx(c)  <=>
sink_pydx5p(c) pydx5p(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_thm(c) thm(c)  <=>
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_thmpp(c) thmpp(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_thm(e) thm(e)  <=>
sink_thmpp(m) thmpp(m)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_thmmp(e) thmmp(e)  <=>
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_thmpp(c) thmpp(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_thmpp(m) thmpp(m)  ->
sink_tyr-L(m) tyr-L(m)  <=>
sink_q10(m) q10(m)  ->
sink_udp(c) udp(c)  <=>
sink_dttp(n) dttp(n)  ->
sink_ump(c) ump(c)  <=>
sink_ala-B(c) ala-B(c)  ->
sink_fru(c) fru(c)  <=>
sink_dhap(c) dhap(c)  ->
sink_fru(c) fru(c)  <=>
sink_g3p(c) g3p(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_fuc-L(c) fuc-L(c)  <=>
sink_gdpfuc(c) gdpfuc(c)  ->
sink_fum(m) fum(m)  <=>
sink_oaa(m) oaa(m)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_g1p(c) g1p(c)  <=>
Warning: Metabolite dtdprmn(c) not in model - added to the model
sink_dtdprmn(c) dtdprmn(c)  ->
sink_g3p(c) g3p(c)  <=>
sink_mthgxl(c) mthgxl(c)  ->
sink_g6p(c) g6p(c)  <=>
sink_r5p(c) r5p(c)  ->
sink_g6p(c) g6p(c)  <=>
```

```
sink_ru5p-D(c) ru5p-D(c)  ->
sink_gal(c) gal(c)  <=>
sink_glc-D(c) glc-D(c)  ->
sink_gal(c) gal(c)  <=>
sink_udpgal(c) udpgal(c)  ->
sink_galgluside_hs(g) galgluside_hs(g)  <=>
sink_galgalgalthcrm_hs(g) galgalgalthcrm_hs(g)  ->
sink_galgluside_hs(g) galgluside_hs(g)  <=>
sink_acgagbside_hs(g) acgagbside_hs(g)  ->
sink_galgluside_hs(g) galgluside_hs(g)  <=>
sink_acnacngalgbside_hs(g) acnacngalgbside_hs(g)  ->
sink_galgluside_hs(g) galgluside_hs(g)  <=>
sink_gd1b2_hs(g) gd1b2_hs(g)  ->
sink_galgluside_hs(g) galgluside_hs(g)  <=>
sink_gd1c_hs(g) gd1c_hs(g)  ->
sink_galgluside_hs(g) galgluside_hs(g)  <=>
sink_gp1c_hs(g) gp1c_hs(g)  ->
sink_galgluside_hs(g) galgluside_hs(g)  <=>
sink_gq1balpha_hs(g) gq1balpha_hs(g)  ->
sink_gam6p(c) gam6p(c)  <=>
sink_uacgam(c) uacgam(c)  ->
sink_gdpmann(c) gdpmann(c)  <=>
sink_gdpfuc(c) gdpfuc(c)  ->
sink_glc-D(c) glc-D(c)  <=>
sink_inost(c) inost(c)  ->
sink_glc-D(c) glc-D(c)  <=>
sink_lac-L(c) lac-L(c)  ->
sink_atp(c) atp(c)  ->
sink_h2o(c) h2o(c)  ->
sink_glc-D(c) glc-D(c)  <=>
sink_lac-D(c) lac-D(c)  ->
sink_glc-D(c) glc-D(c)  <=>
sink_lcts(g) lcts(g)  ->
sink_glc-D(c) glc-D(c)  <=>
sink_pyr(c) pyr(c)  ->
sink_gln-L(c) gln-L(c)  <=>
sink_nh4(c) nh4(c)  ->
sink_gln-L(m) gln-L(m)  <=>
sink_glu-L(m) glu-L(m)  ->
sink_gln-L(m) gln-L(m)  <=>
sink_glu-L(m) glu-L(m)  ->
sink_glu5sa(c) glu5sa(c)  <=>
sink_pro-L(c) pro-L(c)  ->
sink_glu-L(c) glu-L(c)  <=>
sink_4abut(c) 4abut(c)  ->
sink_glu-L(c) glu-L(c)  <=>
sink_gln-L(c) gln-L(c)  ->
sink_glu-L(c) glu-L(c)  <=>
sink_pro-L(c) pro-L(c)  ->
sink_glu-L(m) glu-L(m)  <=>
sink_akg(m) akg(m)  ->
sink_gluside_hs(g) gluside_hs(g)  <=>
sink_galgluside_hs(g) galgluside_hs(g)  ->
sink_glx(m) glx(m)  <=>
sink_glyclt(m) glyclt(m)  ->
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_gly(c) gly(c)  <=>
sink_ser-L(c) ser-L(c)  ->
sink_ser-L(c) ser-L(c)  <=>
sink_pyr(c) pyr(c)  ->
sink_glyc(c) glyc(c)  <=>
sink_glc-D(c) glc-D(c)  ->
sink_glyc(c) glyc(c)  <=>
sink_Rtotal(c) Rtotal(c)  <=>
sink_Rtotal2(c) Rtotal2(c)  <=>
sink_dag_hs(c) dag_hs(c)  ->
Warning: Reaction EX_cbl1(e) not in model
```

```
Warning: Reaction EX_ca2(e) not in model
sink_glyc(c) glyc(c)  <=>
sink_Rtotal(c) Rtotal(c)  <=>
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_tag_hs(c) tag_hs(c)  ->
sink_glyclt(c) glyclt(c)  <=>
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_gly(c) gly(c)  ->
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_glygn2(c) glygn2(c)  <=>
sink_glc-D(c) glc-D(c)  ->
sink_glygn2(e) glygn2(e)  <=>
sink_glc-D(e) glc-D(e)  ->
sink_glx(c) glx(c)  <=>
sink_oxa(c) oxa(c)  ->
sink_ha(l) ha(l)  <=>
sink_acgam(l) acgam(l)  ->
sink_glcur(l) glcur(l)  ->
sink_his-L(c) his-L(c)  <=>
sink_glu-L(c) glu-L(c)  ->
sink_his-L(c) his-L(c)  <=>
sink_hista(c) hista(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_hista(c) hista(c)  <=>
sink_3mlda(c) 3mlda(c)  ->
sink_hista(c) hista(c)  <=>
sink_im4act(c) im4act(c)  ->
sink_hmgcoa(x) hmgcoa(x)  <=>
sink_chsterol(r) chsterol(r)  ->
sink_hmgcoa(x) hmgcoa(x)  <=>
sink_frdp(x) frdp(x)  ->
sink_hmgcoa(x) hmgcoa(x)  <=>
sink_xoldiolone(r) xoldiolone(r)  ->
sink_hmgcoa(x) hmgcoa(x)  <=>
sink_xoltriol(c) xoltriol(c)  ->
sink_hpyr(c) hpyr(c)  <=>
sink_2pg(c) 2pg(c)  ->
sink_hpyr(c) hpyr(c)  <=>
sink_glyclt(c) glyclt(c)  ->
sink_hpyr(c) hpyr(c)  <=>
sink_glyc-S(c) glyc-S(c)  ->
sink_hspg(l) hspg(l)  <=>
sink_gal(l) gal(l)  ->
sink_glcur(l) glcur(l)  ->
sink_xyl-D(l) xyl-D(l)  ->
sink_hyptaur(c) hyptaur(c)  <=>
sink_taur(x) taur(x)  ->
sink_ile-L(c) ile-L(c)  <=>
sink_accoa(c) accoa(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_inost(c) inost(c)  <=>
sink_pail_hs(c) pail_hs(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_inost(c) inost(c)  <=>
sink_pail45p_hs(c) pail45p_hs(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_inost(c) inost(c)  <=>
sink_pail4p_hs(c) pail4p_hs(c)  ->
sink_inost(c) inost(c)  <=>
```

```
sink_xu5p-D(c) xu5p-D(c)  ->
sink_ipdp(x) ipdp(x)  <=>
sink_sql(r) sql(r)  ->
sink_itacon(m) itacon(m)  <=>
sink_pyr(m) pyr(m)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model

sink_ksi(l) ksi(l)  <=>
sink_man(l) man(l)  ->
sink_acgam(l) acgam(l)  ->
sink_ksii_core2(l) ksii_core2(l)  <=>
sink_Ser/Thr(l) Ser/Thr(l)  ->
sink_ksii_core4(l) ksii_core4(l)  <=>
sink_Ser/Thr(l) Ser/Thr(l)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
Warning: Metabolite l2fn2m2masn(g) not in model - added to the model

sink_l2fn2m2masn(g) l2fn2m2masn(g)  <=>
Warning: Metabolite ksi(g) not in model - added to the model

sink_ksi(g) ksi(g)  ->
sink_lac-L(c) lac-L(c)  <=>
sink_glc-D(c) glc-D(c)  ->
sink_Lcyst(c) Lcyst(c)  <=>
sink_taur(x) taur(x)  ->
sink_leu-L(c) leu-L(c)  <=>
sink_accoa(c) accoa(c)  ->
sink_lys-L(c) lys-L(c)  <=>
sink_accoa(m) accoa(m)  ->
sink_lys-L(x) lys-L(x)  <=>
sink_aacoa(m) aacoa(m)  ->
Warning: Metabolite m8masn(r) not in model - added to the model

sink_m8masn(r) m8masn(r)  <=>
Warning: Metabolite nm4masn(g) not in model - added to the model

sink_nm4masn(g) nm4masn(g)  ->
sink_man(c) man(c)  <=>
sink_gdpmann(c) gdpmann(c)  ->
sink_man6p(c) man6p(c)  <=>
sink_kdn(c) kdn(c)  ->
sink_mescon(m) mescon(m)  <=>
sink_pyr(m) pyr(m)  ->
sink_met-L(c) met-L(c)  <=>
sink_cys-L(c) cys-L(c)  ->
sink_mi145p(c) mi145p(c)  <=>
sink_inost(c) inost(c)  ->
sink_msa(m) msa(m)  <=>
sink_ala-B(m) ala-B(m)  ->
sink_mthgxl(c) mthgxl(c)  <=>
sink_12ppd-S(c) 12ppd-S(c)  ->
sink_mthgxl(c) mthgxl(c)  <=>
sink_lac-D(c) lac-D(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model

sink_n2m2nmasn(l) n2m2nmasn(l)  <=>
sink_man(l) man(l)  ->
sink_acgam(l) acgam(l)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
Warning: Metabolite nm4masn(g) not in model - added to the model

sink_nm4masn(g) nm4masn(g)  <=>
Warning: Metabolite l2fn2m2masn(g) not in model - added to the model

sink_l2fn2m2masn(g) l2fn2m2masn(g)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
```

```
Warning: Metabolite nm4masn(g) not in model - added to the model
sink_nm4masn(g) nm4masn(g)  <=>
Warning: Metabolite n2m2nmasn(g) not in model - added to the model
sink_n2m2nmasn(g) n2m2nmasn(g)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
Warning: Metabolite nm4masn(g) not in model - added to the model
sink_nm4masn(g) nm4masn(g)  <=>
Warning: Metabolite s2l2fn2m2masn(g) not in model - added to the model
sink_s2l2fn2m2masn(g) s2l2fn2m2masn(g)  ->
sink_o2s(c) o2s(c)  <=>
sink_h2o2(c) h2o2(c)  ->
sink_h2o2(c) h2o2(c)  <=>
sink_o2(c) o2(c)  <=>
sink_h2o(c) h2o(c)  ->
sink_orn(c) orn(c)  <=>
sink_nh4(c) nh4(c)  ->
sink_orn(c) orn(c)  <=>
sink_ptrc(c) ptrc(c)  ->
sink_orn(c) orn(c)  <=>
sink_spmd(c) spmd(c)  ->
sink_orn(c) orn(c)  <=>
sink_sprm(c) sprm(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_pail_hs(c) pail_hs(c)  <=>
sink_gpi_prot_hs(r) gpi_prot_hs(r)  ->
sink_pail45p_hs(c) pail45p_hs(c)  <=>
sink_mi145p(c) mi145p(c)  ->
sink_phe-L(c) phe-L(c)  <=>
sink_pac(c) pac(c)  ->
sink_phe-L(c) phe-L(c)  <=>
sink_pacald(c) pacald(c)  ->
sink_phe-L(c) phe-L(c)  <=>
sink_peamn(c) peamn(c)  ->
sink_phe-L(c) phe-L(c)  <=>
sink_phaccoa(c) phaccoa(c)  ->
sink_phe-L(c) phe-L(c)  <=>
sink_pheacgln(c) pheacgln(c)  ->
sink_phe-L(c) phe-L(c)  <=>
sink_phpyr(c) phpyr(c)  ->
sink_phe-L(c) phe-L(c)  <=>
sink_tyr-L(c) tyr-L(c)  ->
sink_pheme(c) pheme(c)  <=>
sink_bilirub(c) bilirub(c)  ->
sink_phytcoa(x) phytcoa(x)  <=>
sink_dmnoncoa(m) dmnoncoa(m)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_pmtcoa(c) pmtcoa(c)  <=>
sink_crmp_hs(c) crmp_hs(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_pmtcoa(c) pmtcoa(c)  <=>
sink_sphmyln_hs(c) sphmyln_hs(c)  ->
sink_ppcoa(m) ppcoa(m)  <=>
sink_succoa(m) succoa(m)  ->
sink_pro-L(c) pro-L(c)  <=>
sink_glu-L(c) glu-L(c)  ->
sink_ptrc(c) ptrc(c)  <=>
sink_ala-B(c) ala-B(c)  ->
```

```
sink_ptrc(c) ptrc(c)  <=>
sink_spmd(c) spmd(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model

sink_pyr(c) pyr(c)  <=>
sink_fadh2(m) fadh2(m)  <=>
sink_fad(m) fad(m)  ->
sink_h(m) h(m)  ->
sink_pyr(c) pyr(c)  <=>
sink_lac-D(c) lac-D(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model

sink_pyr(c) pyr(c)  <=>
sink_nad(m) nad(m)  ->
sink_h(m) h(m)  ->
sink_pyr(c) pyr(c)  <=>
sink_accoa(m) accoa(m)  ->
sink_nadh(m) nadh(m)  ->
sink_co2(c) co2(c)  ->
sink_pyr(c) pyr(c)  <=>
sink_ala-L(c) ala-L(c)  ->
sink_ala-L(c) ala-L(c)  <=>
sink_pyr(c) pyr(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model

sink_s2l2fn2m2masn(l) s2l2fn2m2masn(l)  <=>
sink_man(l) man(l)  ->
sink_acgam(l) acgam(l)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model

sink_Ser/Thr(g) Ser/Thr(g)  <=>
sink_udpacgal(g) udpacgal(g)  <=>
sink_core2(g) core2(g)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model

sink_Ser/Thr(g) Ser/Thr(g)  <=>
sink_udpacgal(g) udpacgal(g)  <=>
sink_core4(g) core4(g)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model

sink_Ser/Thr(g) Ser/Thr(g)  <=>
sink_udpacgal(g) udpacgal(g)  <=>
sink_Tn_antigen(g) Tn_antigen(g)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model

sink_Ser/Thr(g) Ser/Thr(g)  <=>
sink_udpacgal(g) udpacgal(g)  <=>
sink_sTn_antigen(g) sTn_antigen(g)  ->
sink_Ser-Gly/Ala-X-Gly(r) Ser-Gly/Ala-X-Gly(r)  <=>
sink_cs_pre(g) cs_pre(g)  ->
sink_Ser-Gly/Ala-X-Gly(r) Ser-Gly/Ala-X-Gly(r)  <=>
sink_cspg_a(g) cspg_a(g)  ->
sink_Ser-Gly/Ala-X-Gly(r) Ser-Gly/Ala-X-Gly(r)  <=>
sink_cspg_c(g) cspg_c(g)  ->
sink_Ser-Gly/Ala-X-Gly(r) Ser-Gly/Ala-X-Gly(r)  <=>
sink_cspg_d(g) cspg_d(g)  ->
sink_Ser-Gly/Ala-X-Gly(r) Ser-Gly/Ala-X-Gly(r)  <=>
sink_cspg_e(g) cspg_e(g)  ->
sink_Ser-Gly/Ala-X-Gly(r) Ser-Gly/Ala-X-Gly(r)  <=>
sink_hspg(g) hspg(g)  ->
sink_Ser-Gly/Ala-X-Gly(r) Ser-Gly/Ala-X-Gly(r)  <=>
sink_cspg_b(g) cspg_b(g)  ->
sink_ser-L(c) ser-L(c)  <=>
```

```
sink_cys-L(c) cys-L(c)  ->
sink_so4(c) so4(c)  <=>
sink_paps(c) paps(c)  ->
sink_spmd(c) spmd(c)  <=>
sink_sprm(c) sprm(c)  ->
sink_srtn(c) srtn(c)  <=>
Warning: Metabolite f5hoxkyn(c) not in model - added to the model
sink_f5hoxkyn(c) f5hoxkyn(c)  ->
sink_srtn(c) srtn(c)  <=>
sink_fna5moxam(c) fna5moxam(c)  ->
sink_srtn(c) srtn(c)  <=>
Warning: Metabolite nmthsrtn(c) not in model - added to the model
sink_nmthsrtn(c) nmthsrtn(c)  ->
sink_succoa(m) succoa(m)  <=>
sink_oaa(m) oaa(m)  ->
sink_taur(x) taur(x)  <=>
sink_tchola(x) tchola(x)  ->
sink_thcholstoic(x) thcholstoic(x)  <=>
sink_gchola(x) gchola(x)  ->
sink_thcholstoic(x) thcholstoic(x)  <=>
sink_tchola(x) tchola(x)  ->
sink_trp-L(c) trp-L(c)  <=>
sink_ppcoa(c) ppcoa(c)  ->
sink_trp-L(c) trp-L(c)  <=>
sink_accoa(c) accoa(c)  ->
sink_trp-L(c) trp-L(c)  <=>
sink_anth(c) anth(c)  ->
sink_trp-L(c) trp-L(c)  <=>
sink_id3acald(c) id3acald(c)  ->
sink_trp-L(c) trp-L(c)  <=>
sink_kynate(c) kynate(c)  ->
sink_trp-L(c) trp-L(c)  <=>
sink_melatn(c) melatn(c)  ->
sink_trp-L(c) trp-L(c)  <=>
sink_Lfmkynr(c) Lfmkynr(c)  ->
sink_trp-L(c) trp-L(c)  <=>
sink_Lkynr(c) Lkynr(c)  ->
sink_trp-L(c) trp-L(c)  <=>
sink_nformanth(c) nformanth(c)  ->
sink_srtn(c) srtn(c)  <=>
Warning: Metabolite 5moxact(c) not in model - added to the model
sink_5moxact(c) 5moxact(c)  ->
sink_srtn(c) srtn(c)  <=>
sink_6hoxmelatn(c) 6hoxmelatn(c)  ->
sink_trp-L(c) trp-L(c)  <=>
sink_quln(c) quln(c)  ->
sink_trp-L(c) trp-L(c)  <=>
sink_srtn(c) srtn(c)  ->
sink_Tyr-ggn(c) Tyr-ggn(c)  <=>
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_glygn2(c) glygn2(c)  ->
sink_tyr-L(c) tyr-L(c)  <=>
sink_34hpp(c) 34hpp(c)  ->
sink_tyr-L(c) tyr-L(c)  <=>
sink_4hphac(c) 4hphac(c)  ->
sink_tyr-L(c) tyr-L(c)  <=>
sink_adrnl(c) adrnl(c)  ->
sink_tyr-L(c) tyr-L(c)  <=>
sink_dopa(c) dopa(c)  ->
sink_tyr-L(c) tyr-L(c)  <=>
sink_fum(c) fum(c)  ->
sink_acac(c) acac(c)  ->
sink_tyr-L(c) tyr-L(c)  <=>
sink_melanin(c) melanin(c)  ->
sink_tyr-L(c) tyr-L(c)  <=>
```

```
sink_nrpphr(c) nrpphr(c)  ->
sink_uacgam(c) uacgam(c)  <=>
sink_udpglcur(c) udpglcur(c)  <=>
sink_ha(e) ha(e)  ->
sink_uacgam(c) uacgam(c)  <=>
Warning: Metabolite m8masn(r) not in model - added to the model
sink_m8masn(r) m8masn(r)  ->
sink_udpglcur(c) udpglcur(c)  <=>
sink_xu5p-D(c) xu5p-D(c)  ->
sink_ura(c) ura(c)  <=>
sink_ala-B(c) ala-B(c)  ->
sink_val-L(c) val-L(c)  <=>
sink_3aib(c) 3aib(c)  ->
sink_val-L(c) val-L(c)  <=>
sink_succoa(m) succoa(m)  ->
sink_xoltriol(m) xoltriol(m)  <=>
sink_thcholstoic(m) thcholstoic(m)  ->
sink_xylu-D(c) xylu-D(c)  <=>
sink_glyclt(c) glyclt(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
FBA =
          full: [10600×1 double]
           obj: 4.0000
         rcost: [10600×1 double]
          dual: [5835×1 double]
        solver: 'tomlab_cplex'
     algorithm: 'default'
          stat: 1
       origStat: 1
          time: 0.4470
         basis: [16435×1 double]
             x: [10600×1 double]
             f: 4.0000
             y: [5835×1 double]
             w: [10600×1 double]
             v: [10600×1 double]
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_pyr(m) pyr(m)  ->
sink_pyr(c) pyr(c)  ->
sink_pyr(c) pyr(c)  ->
sink_ala-L(c) ala-L(c)  ->
sink_pyr(c) pyr(c)  ->
sink_ala-L(c) ala-L(c)  ->
sink_ala-L(c) ala-L(c)  ->
sink_ala-L(c) ala-L(c)  ->
sink_gln-L(c) gln-L(c)  ->
sink_gln-L(c) gln-L(c)  ->
sink_gln-L(c) gln-L(c)  ->
sink_gln-L(c) gln-L(c)  ->
sink_ala-L(c) ala-L(c)  ->
sink_gln-L(c) gln-L(c)  ->
sink_ala-L(c) ala-L(c)  ->
sink_gln-L(c) gln-L(c)  ->
sink_ala-L(c) ala-L(c)  ->
sink_gln-L(c) gln-L(c)  ->
sink_ala-L(c) ala-L(c)  ->
sink_gln-L(c) gln-L(c)  ->
sink_ala-L(c) ala-L(c)  ->
sink_orn(c) orn(c)  ->
sink_pro-L(c) pro-L(c)  ->
sink_ptrc(c) ptrc(c)  ->
sink_gln-L(c) gln-L(c)  ->
sink_sprm(c) sprm(c)  ->
```

```
sink_spmd(c) spmd(c)  ->
sink_ptrc(c) ptrc(c)  ->
Warning: Reaction with the same name already exists in the model, updating the reaction
Warning: Metabolite pcreat[e] not in model - added to the model
EX_pcreat(e) pcreat[e]  ->
sink_creat(c) creat(c)  ->
sink_pcreat(c) pcreat(c)  ->
sink_lac-L(c) lac-L(c)  ->
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_glygn2(c) glygn2(c)  ->
sink_e4p(c) e4p(c)  ->
sink_mag-hs(c) mag-hs(c)  ->
sink_glyc(c) glyc(c)  ->
sink_accoa(m) accoa(m)  ->
sink_accoa(m) accoa(m)  ->
sink_accoa(m) accoa(m)  ->
sink_dhap(c) dhap(c)  ->
sink_amp(c) amp(c)  ->
sink_imp(c) imp(c)  ->
sink_prpp(c) prpp(c)  <=>
sink_gmp(c) gmp(c)  ->
sink_imp(c) imp(c)  ->
sink_thym(c) thym(c)  ->
sink_cmp(c) cmp(c)  ->
sink_dtmp(c) dtmp(c)  ->
sink_citr-L(c) citr-L(c)  <=>
sink_arg-L(c) arg-L(c)  ->
sink_cys-L(c) cys-L(c)  <=>
sink_taur(c) taur(c)  ->
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_gly(c) gly(c)  <=>
sink_orn(c) orn(c)  ->
sink_citr-L(c) citr-L(c)  <=>
sink_urea(c) urea(c)  ->
Warning: Reaction with the same name already exists in the model, updating the reaction
sink_gly(c) gly(c)  <=>
sink_gthrd(c) gthrd(c)  ->
sink_pro-L(c) pro-L(c)  <=>
sink_4abut(c) 4abut(c)  ->
sink_pro-L(c) pro-L(c)  <=>
sink_orn(c) orn(c)  ->
sink_met-L(c) met-L(c)  <=>
sink_hcys-L(c) hcys-L(c)  ->
sink_hcys-L(c) hcys-L(c)  <=>
sink_met-L(c) met-L(c)  ->
sink_hcys-L(c) hcys-L(c)  <=>
sink_cys-L(c) cys-L(c)  ->
sink_lys-L(c) lys-L(c)  <=>
sink_glu-L(c) glu-L(c)  ->
sink_trp-L(c) trp-L(c)  <=>
sink_trypta(c) trypta(c)  ->
sink_kynate(c) kynate(c)  <=>
sink_nicrnt(c) nicrnt(c)  ->
sink_pyr(c) pyr(c)  <=>
sink_lac-L(c) lac-L(c)  ->
sink_gal(c) gal(c)  <=>
sink_udpg(c) udpg(c)  ->
sink_fru(c) fru(c)  <=>
sink_lac-L(c) lac-L(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_malcoa(c) malcoa(c)  <=>
sink_eicostetcoa(c) eicostetcoa(c)  ->
sink_accoa(c) accoa(c)  <=>
```

```
sink_chsterol(r) chsterol(r)  ->
sink_inost(c) inost(c)  <=>
sink_glac(r) glac(r)  ->
sink_pail_hs(c) pail_hs(c)  <=>
sink_pail4p_hs(c) pail4p_hs(c)  ->
sink_arachd(c) arachd(c)  <=>
sink_prostgh2(c) prostgh2(c)  ->
sink_arachd(c) arachd(c)  <=>
sink_prostgd2(r) prostgd2(r)  ->
sink_arachd(c) arachd(c)  <=>
sink_prostge2(r) prostge2(r)  ->
sink_arachd(c) arachd(c)  <=>
sink_prostgi2(r) prostgi2(r)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model

sink_25hvitd3(m) 25hvitd3(m)  <=>
sink_2425dhvitd3(m) 2425dhvitd3(m)  ->
sink_caro(c) caro(c)  <=>
sink_retinal(c) retinal(c)  ->
Warning: Model already has the same reaction you tried to add: sink_glu_L(c)
```

```
DM_pro-L(m) pro-L(m)  ->
sink_retinol-cis-11(c) retinol-cis-11(c)  <=>
sink_retinal(c) retinal(c)  ->
sink_pail_hs(c) pail_hs(c)  <=>
sink_pchol-hs(c) pchol-hs(c)  ->
sink_pail_hs(c) pail_hs(c)  <=>
sink_pe_hs(c) pe_hs(c)  ->
sink_pail_hs(c) pail_hs(c)  <=>
sink_ps-hs(c) ps-hs(c)  ->
sink_pail_hs(c) pail_hs(c)  <=>
sink_g3pc(c) g3pc(c)  ->
sink_dag_hs(c) dag_hs(c)  <=>
sink_pchol-hs(c) pchol-hs(c)  ->
sink_dag_hs(c) dag_hs(c)  <=>
sink_pe_hs(c) pe_hs(c)  ->
sink_dag_hs(c) dag_hs(c)  <=>
sink_clpn-hs(c) clpn-hs(c)  ->
sink_dag_hs(c) dag_hs(c)  <=>
sink_pgp-hs(c) pgp-hs(c)  ->
sink_bhb(m) bhb(m)  <=>
sink_acac(m) acac(m)  ->
sink_mal-L(m) mal-L(m)  <=>
sink_pyr(m) pyr(m)  ->
sink_glu-L(c) glu-L(c)  <=>
sink_gln-L(c) gln-L(c)  ->
sink_cys-L(c) cys-L(c)  <=>
```

```
Warning: Reaction with the same name already exists in the model, updating the reaction

sink_coa(c) coa(c)  ->
sink_occoa(m) occoa(m)  <=>
sink_accoa(m) accoa(m)  ->
Warning: Reaction with the same name already exists in the model, updating the reaction

sink_lnlncgcoa(c) lnlncgcoa(c)  <=>
sink_dlnlcgcoa(c) dlnlcgcoa(c)  ->
Warning: Reaction with the same name already exists in the model, updating the reaction

sink_chol(c) chol(c)  <=>
sink_ach(c) ach(c)  ->
sink_pyr(m) pyr(m)  <=>
sink_oaa(m) oaa(m)  ->
sink_crtn(c) crtn(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model

sink_arachd(c) arachd(c)  <=>
sink_leuktrE4(c) leuktrE4(c)  ->
Warning: Reaction EX_cbl1(e) not in model
```

```
Warning: Reaction EX_ca2(e) not in model
sink_arachd(c) arachd(c)  <=>
sink_C06314(c) C06314(c)  ->
Warning: Reaction EX_cbl1(e) not in model
Warning: Reaction EX_ca2(e) not in model
sink_nrpphr(c) nrpphr(c)  <=>
sink_3mox4hoxm(c) 3mox4hoxm(c)  ->
sink_sbt-D(c) sbt-D(c)  <=>
sink_fru(c) fru(c)  ->
sink_accoa(m) accoa(m)  ->
sink_succoa(m) succoa(m)  ->
```

```
TestedRxns = unique([TestedRxnsC; TestedRxnsClosedSinks]);
TestedRxnsX = intersect(model.rxns,TestedRxns);
```

In this example, we aim to remove all HMR reactions (i.e., those reactions originating from HMR 2.0 [2] and that start with 'HMR_') that are not needed for the aforementioned tasks.

```
HMR = model.rxns(strmatch('HMR_',model.rxns));
HMR_NE = setdiff(HMR,TestedRxnsX);
model.lb(find(ismember(model.rxns,HMR_NE))) = 0;
model.ub(find(ismember(model.rxns,HMR_NE))) = 0;
```

We will also remove all drug module reactions, i.e., those ones with the term 'Xeno' in the subsystem, mostly originating from [3].

```
DM = model.rxns(strmatch('Xeno',model.subSystems));
model.lb(find(ismember(model.rxns,DM))) = 0;
model.ub(find(ismember(model.rxns,DM))) = 0;
DMt = (strmatch('Transport of Xenobiotic',model.rxnNames));
model.lb(DMt) = 0;
model.ub(DMt) = 0;
```

We will also remove all reactions from the 'Peptide metabolism' subsystem.

```
DM = model.rxns(strmatch('Peptide metabolism',model.subSystems));
model.lb(find(ismember(model.rxns,DM))) = 0;
model.ub(find(ismember(model.rxns,DM))) = 0;
```

Now we will ensure that the reversibility of each reaction is in accordance to the defined lower bound.

```
model.rev(find(model.lb<0))=1;
model.rev(find(model.lb>=0))=0;
```

We will use fastcc [4[, to ensure a flux-consistent subnetwork.

```
param.epsilon=1e-4;
param.modeFlag=0;
%param.method='null_fastcc';
param.method='fastcc';
printLevel=3;
[fluxConsistentMetBool,fluxConsistentRxnBool,fluxInConsistentMetBool,fluxInConsistentRxnBool,m
```

```
 10600 Total reactions
  4402 Reversible reactions.
  6198 Irreversible reactions.
  7453 Flux consistent reactions, without flipping.
```

```
2020 Flux inconsistent irreversible reactions, without flipping.
1127 Flux inconsistent reactions, without flipping.
7706 Flux consistent reactions.
 874 Flux inconsistent reversible reactions left to flip.
7709 Flux consistent reactions.
 871 Flux inconsistent reversible reactions left to flip.
7711 Flux consistent reactions.
 869 Flux inconsistent reversible reactions left to flip.
7715 Flux consistent reactions.
 855 Flux inconsistent reversible reactions left to flip.
7717 Flux consistent reactions.
 833 Flux inconsistent reversible reactions left to flip.
7719 Flux consistent reactions.
 720 Flux inconsistent reversible reactions left to flip.
7721 Flux consistent reactions.
 718 Flux inconsistent reversible reactions left to flip.
```

And remove the flux inconsistent reactions from the model.

```
modelConsistent = removeRxns(model,model.rxns(find(fluxInConsistentRxnBool)));
```

We will now update the GPR associations.

```
modelConsistent.genes = [];
modelConsistent.rxnGeneMat = [];
modelgrRule = modelConsistent.grRules;
for i = 1 : length(modelgrRule)
    if ~isempty(modelgrRule{i})
        modelConsistent = changeGeneAssociation(modelConsistent,modelConsistent.rxns{i},modelg
    end
end
```

```
New gene 8639.1 added to model
New gene 26.1 added to model
New gene 314.2 added to model
New gene 314.1 added to model
New gene 1591.1 added to model
New gene 10993.1 added to model
New gene 6818.1 added to model
New gene 89874.1 added to model
New gene 92483.1 added to model
New gene 3948.2 added to model
New gene 55293.1 added to model
New gene 3945.1 added to model
New gene 3939.1 added to model
New gene 160287.1 added to model
New gene 3948.1 added to model
New gene 9123.1 added to model
New gene 9194.1 added to model
New gene 6566.1 added to model
New gene 57835.3 added to model
New gene 8671.1 added to model
New gene 57835.2 added to model
New gene 57835.1 added to model
New gene 57835.4 added to model
New gene 4967.2 added to model
New gene 1738.1 added to model
New gene 8050.1 added to model
New gene 1743.1 added to model
New gene 4967.1 added to model
New gene 130.1 added to model
```

New gene 127.1 added to model
New gene 125.1 added to model
New gene 124.1 added to model
New gene 131.1 added to model
New gene 126.1 added to model
New gene 128.1 added to model
New gene 137872.1 added to model
New gene 1312.1 added to model
New gene 1312.2 added to model
New gene 117247.1 added to model
New gene 218.1 added to model
New gene 222.1 added to model
New gene 220.1 added to model
New gene 221.1 added to model
New gene 3242.1 added to model
New gene 18.1 added to model
New gene 18.2 added to model
New gene 2531.1 added to model
New gene 23498.1 added to model
New gene 55268.1 added to model
New gene 51166.1 added to model
New gene 883.1 added to model
New gene 51166.2 added to model
New gene 1644.1 added to model
New gene 4128.1 added to model
New gene 4129.1 added to model
New gene 10165.1 added to model
New gene 8604.1 added to model
New gene 51380.1 added to model
New gene 2571.1 added to model
New gene 2572.1 added to model
New gene 2571.2 added to model
New gene 2805.1 added to model
New gene 2806.1 added to model
New gene 8659.1 added to model
New gene 8659.2 added to model
New gene 4363.1 added to model
New gene 6822.1 added to model
New gene 6573.1 added to model
New gene 6573.2 added to model
New gene 316.1 added to model
New gene 6570.1 added to model
New gene 6571.1 added to model
New gene 2348.5 added to model
New gene 2348.3 added to model
New gene 2348.1 added to model
New gene 2348.6 added to model
New gene 2352.1 added to model
New gene 2348.4 added to model
New gene 2348.2 added to model
New gene 4125.1 added to model
New gene 53947.1 added to model
New gene 51146.1 added to model
New gene 28.1 added to model
New gene 206358.1 added to model
New gene 6529.1 added to model
New gene 6538.1 added to model
New gene 6540.1 added to model
New gene 6539.1 added to model
New gene 38.1 added to model

New gene 3032.1 added to model
New gene 10449.1 added to model
New gene 3030.1 added to model
New gene 39.1 added to model
New gene 30.1 added to model
New gene 32.1 added to model
New gene 9197.1 added to model
New gene 84532.1 added to model
New gene 79611.1 added to model
New gene 64841.1 added to model
New gene 55577.1 added to model
New gene 5238.1 added to model
New gene 162417.1 added to model
New gene 43.1 added to model
New gene 43.2 added to model
New gene 6572.1 added to model
New gene 47.1 added to model
New gene 47.2 added to model
New gene 54187.1 added to model
New gene 26503.1 added to model
New gene 140838.1 added to model
New gene 54.1 added to model
New gene 51205.1 added to model
New gene 36.1 added to model
New gene 34.1 added to model
New gene 80724.1 added to model
New gene 35.1 added to model
New gene 84129.1 added to model
New gene 27034.1 added to model
New gene 28976.1 added to model
New gene 3712.1 added to model
New gene 134526.1 added to model
New gene 51.1 added to model
New gene 51.2 added to model
New gene 95.1 added to model
New gene 50.1 added to model
New gene 48.1 added to model
New gene 8309.1 added to model
New gene 52.1 added to model
New gene 52.3 added to model
New gene 52.2 added to model
New gene 55.1 added to model
New gene 788.1 added to model
New gene 55902.1 added to model
New gene 65985.1 added to model
New gene 55902.2 added to model
New gene 438.1 added to model
New gene 1571.1 added to model
New gene 100.1 added to model
New gene 3177.1 added to model
New gene 205.3 added to model
New gene 205.1 added to model
New gene 204.1 added to model
New gene 204.3 added to model
New gene 204.2 added to model
New gene 205.2 added to model
New gene 26289.1 added to model
New gene 26289.2 added to model

New gene 50808.1 added to model
New gene 262.1 added to model
New gene 112.1 added to model
New gene 55811.1 added to model
New gene 109.1 added to model
New gene 112.2 added to model
New gene 114.1 added to model
New gene 108.1 added to model
New gene 113.1 added to model
New gene 107.1 added to model
New gene 196883.1 added to model
New gene 115.1 added to model
New gene 111.1 added to model
New gene 2030.1 added to model
New gene 9154.2 added to model
New gene 9154.1 added to model
New gene 64078.1 added to model
New gene 9153.1 added to model
New gene 952.1 added to model
New gene 1375.1 added to model
New gene 1375.3 added to model
New gene 1375.4 added to model
New gene 126129.1 added to model
New gene 1374.1 added to model
New gene 1375.2 added to model
New gene 1376.1 added to model
New gene 9060.1 added to model
New gene 9061.1 added to model
New gene 158.1 added to model
New gene 158.2 added to model
New gene 79369.1 added to model
New gene 10678.1 added to model
New gene 11041.1 added to model
New gene 146712.1 added to model
New gene 374907.1 added to model
New gene 93010.1 added to model
New gene 374907.2 added to model
New gene 10678.2 added to model
New gene 10331.1 added to model
New gene 79814.1 added to model
New gene 10555.1 added to model
New gene 137964.1 added to model
New gene 56895.1 added to model
New gene 56894.2 added to model
New gene 56894.1 added to model
New gene 55326.1 added to model
New gene 10554.1 added to model
New gene 129642.1 added to model
New gene 64902.1 added to model
New gene 64850.1 added to model
New gene 189.1 added to model
New gene 3073.1 added to model
New gene 3074.1 added to model
New gene 10606.1 added to model
New gene 8402.1 added to model
New gene 1468.1 added to model
New gene 64849.1 added to model
New gene 64849.2 added to model
New gene 1645.1 added to model
New gene 1109.1 added to model
New gene 6718.1 added to model

New gene 6510.1 added to model
New gene 6509.1 added to model
New gene 56301.1 added to model
New gene 6520.1 added to model
New gene 212.1 added to model
New gene 23464.1 added to model
New gene 211.2 added to model
New gene 211.1 added to model
New gene 54407.1 added to model
New gene 6542.1 added to model
New gene 11254.1 added to model
New gene 6541.1 added to model
New gene 81539.1 added to model
New gene 55089.1 added to model
New gene 84889.1 added to model
New gene 340024.1 added to model
New gene 57393.1 added to model
New gene 59272.1 added to model
New gene 2875.1 added to model
New gene 84706.1 added to model
New gene 92745.1 added to model
New gene 10991.1 added to model
New gene 284273.2 added to model
New gene 284273.1 added to model
New gene 10327.1 added to model
New gene 10327.2 added to model
New gene 216.1 added to model
New gene 8854.2 added to model
New gene 501.1 added to model
New gene 8854.1 added to model
New gene 223.1 added to model
New gene 224.1 added to model
New gene 8854.3 added to model
New gene 219.1 added to model
New gene 217.1 added to model
New gene 239.1 added to model
New gene 247.1 added to model
New gene 246.1 added to model
New gene 240.1 added to model
New gene 8574.1 added to model
New gene 231.1 added to model
New gene 23600.1 added to model
New gene 23600.2 added to model
New gene 115286.3 added to model
New gene 115286.2 added to model
New gene 115286.1 added to model
New gene 271.2 added to model
New gene 270.1 added to model
New gene 271.1 added to model
New gene 272.1 added to model
New gene 271.3 added to model
New gene 290.1 added to model
New gene 280.1 added to model
New gene 278.1 added to model
New gene 276.1 added to model
New gene 277.1 added to model
New gene 6519.1 added to model
New gene 11136.1 added to model
New gene 276.2 added to model
New gene 279.1 added to model
New gene 10998.1 added to model

```
New gene 113451.1 added to model
New gene 9057.1 added to model
New gene 384.1 added to model
New gene 445.1 added to model
New gene 445.2 added to model
New gene 83884.1 added to model
New gene 10166.1 added to model
New gene 410.1 added to model
New gene 427.1 added to model
New gene 427.2 added to model
New gene 9962.2 added to model
New gene 9963.1 added to model
New gene 9962.1 added to model
New gene 9963.2 added to model
New gene 80150.1 added to model
New gene 440.1 added to model
New gene 440.3 added to model
New gene 440.2 added to model
New gene 790.1 added to model
New gene 6511.1 added to model
New gene 6505.1 added to model
New gene 6507.1 added to model
New gene 6506.1 added to model
New gene 6512.1 added to model
New gene 50617.1 added to model
New gene 533.1 added to model
New gene 527.1 added to model
New gene 8992.1 added to model
New gene 245972.1 added to model
New gene 9114.1 added to model
New gene 535.1 added to model
New gene 50617.3 added to model
New gene 10312.1 added to model
New gene 50617.2 added to model
New gene 23545.1 added to model
New gene 10312.2 added to model
New gene 51382.1 added to model
New gene 9296.1 added to model
New gene 529.1 added to model
New gene 245973.1 added to model
New gene 523.1 added to model
New gene 51606.1 added to model
New gene 9550.1 added to model
New gene 526.1 added to model
New gene 127124.1 added to model
New gene 525.1 added to model
New gene 90423.1 added to model
New gene 51606.2 added to model
New gene 51606.3 added to model
New gene 534.2 added to model
New gene 528.2 added to model
New gene 534.1 added to model
New gene 528.1 added to model
New gene 127124.2 added to model
New gene 954.1 added to model
New gene 954.2 added to model
New gene 953.1 added to model
New gene 956.1 added to model
New gene 955.1 added to model
New gene 957.1 added to model
New gene 377841.1 added to model
New gene 291.1 added to model
New gene 293.1 added to model
```

New gene 292.1 added to model
New gene 4126.1 added to model
New gene 8706.4 added to model
New gene 8706.1 added to model
New gene 8706.3 added to model
New gene 8706.2 added to model
New gene 8705.1 added to model
New gene 10317.4 added to model
New gene 10317.1 added to model
New gene 10317.3 added to model
New gene 10317.2 added to model
New gene 10317.5 added to model
New gene 84002.1 added to model
New gene 570.1 added to model
New gene 3141.1 added to model
New gene 140679.1 added to model
New gene 8424.1 added to model
New gene 53630.1 added to model
New gene 622.2 added to model
New gene 622.3 added to model
New gene 622.1 added to model
New gene 23743.1 added to model
New gene 635.1 added to model
New gene 10599.1 added to model
New gene 1244.1 added to model
New gene 8714.1 added to model
New gene 28234.1 added to model
New gene 645.1 added to model
New gene 644.1 added to model
New gene 10380.1 added to model
New gene 686.1 added to model
New gene 8884.1 added to model
New gene 80704.1 added to model
New gene 51733.1 added to model
New gene 7108.1 added to model
New gene 50814.1 added to model
New gene 3295.1 added to model
New gene 6307.1 added to model
New gene 492.1 added to model
New gene 491.1 added to model
New gene 490.1 added to model
New gene 493.1 added to model
New gene 847.1 added to model
New gene 6547.6 added to model
New gene 6547.4 added to model
New gene 6547.2 added to model
New gene 6546.1 added to model
New gene 6547.1 added to model
New gene 6547.5 added to model
New gene 6543.1 added to model
New gene 6547.3 added to model
New gene 166785.1 added to model
New gene 2538.1 added to model
New gene 57818.1 added to model
New gene 92579.1 added to model
New gene 1373.1 added to model
New gene 1373.2 added to model
New gene 873.1 added to model

New gene 10423.1 added to model
New gene 10423.2 added to model
New gene 1040.1 added to model
New gene 8760.1 added to model
New gene 10390.1 added to model
New gene 56994.1 added to model
New gene 64781.1 added to model
New gene 64781.2 added to model
New gene 10087.1 added to model
New gene 6565.1 added to model
New gene 9023.1 added to model
New gene 1103.4 added to model
New gene 1103.2 added to model
New gene 1103.3 added to model
New gene 1103.1 added to model
New gene 162466.1 added to model
New gene 5130.1 added to model
New gene 9468.1 added to model
New gene 6579.1 added to model
New gene 6554.1 added to model
New gene 6555.1 added to model
New gene 8714.3 added to model
New gene 8647.1 added to model
New gene 8714.2 added to model
New gene 55349.1 added to model
New gene 1120.2 added to model
New gene 1119.1 added to model
New gene 1120.1 added to model
New gene 1119.2 added to model
New gene 60482.1 added to model
New gene 6582.1 added to model
New gene 6584.1 added to model
New gene 6582.2 added to model
New gene 6820.1 added to model
New gene 10948.1 added to model
New gene 27159.2 added to model
New gene 9058.1 added to model
New gene 6576.1 added to model
New gene 1159.1 added to model
New gene 1160.1 added to model
New gene 548596.1 added to model
New gene 1152.1 added to model
New gene 1158.1 added to model
New gene 5172.1 added to model
New gene 65010.1 added to model
New gene 65010.3 added to model
New gene 65010.2 added to model
New gene 54675.1 added to model
New gene 10559.1 added to model
New gene 55907.1 added to model
New gene 8034.1 added to model
New gene 8824.1 added to model
New gene 51805.1 added to model
New gene 51004.1 added to model
New gene 51004.2 added to model
New gene 10229.1 added to model
New gene 9245.1 added to model
New gene 2650.1 added to model

New gene 51301.1 added to model
New gene 192134.1 added to model
New gene 6535.1 added to model
New gene 386757.1 added to model
New gene 1384.1 added to model
New gene 6583.1 added to model
New gene 1431.1 added to model
New gene 1431.2 added to model
New gene 54677.1 added to model
New gene 1384.2 added to model
New gene 1384.3 added to model
New gene 8140.1 added to model
New gene 23428.1 added to model
New gene 23428.2 added to model
New gene 1036.1 added to model
New gene 124935.1 added to model
New gene 23657.1 added to model
New gene 978.1 added to model
New gene 57379.1 added to model
New gene 7371.1 added to model
New gene 83549.1 added to model
New gene 51727.1 added to model
New gene 129607.1 added to model
New gene 9162.1 added to model
New gene 1607.1 added to model
New gene 8525.2 added to model
New gene 160851.1 added to model
New gene 1608.1 added to model
New gene 1607.2 added to model
New gene 8525.1 added to model
New gene 8527.1 added to model
New gene 1606.1 added to model
New gene 160851.2 added to model
New gene 8526.1 added to model
New gene 8525.3 added to model
New gene 8527.2 added to model
New gene 1609.1 added to model
New gene 1610.1 added to model
New gene 2745.1 added to model
New gene 51022.2 added to model
New gene 51022.1 added to model
New gene 8528.2 added to model
New gene 8528.1 added to model
New gene 1633.1 added to model
New gene 1638.1 added to model
New gene 6319.1 added to model
New gene 9415.1 added to model
New gene 3992.1 added to model
New gene 8694.1 added to model
New gene 84649.1 added to model
New gene 1716.5 added to model
New gene 1716.1 added to model
New gene 1716.4 added to model
New gene 1716.2 added to model
New gene 1716.3 added to model
New gene 6515.1 added to model
New gene 6513.1 added to model
New gene 6517.1 added to model
New gene 1718.1 added to model

New gene 1581.1 added to model
New gene 1717.1 added to model
New gene 8560.1 added to model
New gene 8560.2 added to model
New gene 123099.1 added to model
New gene 11309.1 added to model
New gene 6783.1 added to model
New gene 1723.1 added to model
New gene 1807.1 added to model
New gene 1809.1 added to model
New gene 1808.1 added to model
New gene 23539.1 added to model
New gene 2224.1 added to model
New gene 29958.1 added to model
New gene 60386.1 added to model
New gene 84920.1 added to model
New gene 26002.1 added to model
New gene 1621.1 added to model
New gene 7299.1 added to model
New gene 6799.1 added to model
New gene 6817.3 added to model
New gene 6799.2 added to model
New gene 6818.2 added to model
New gene 6817.2 added to model
New gene 6817.1 added to model
New gene 6817.4 added to model
New gene 6818.3 added to model
New gene 6817.5 added to model
New gene 6530.1 added to model
New gene 6531.1 added to model
New gene 6581.1 added to model
New gene 669.2 added to model
New gene 5223.1 added to model
New gene 5224.2 added to model
New gene 5224.1 added to model
New gene 669.1 added to model
New gene 4597.1 added to model
New gene 51071.1 added to model
New gene 1806.1 added to model
New gene 7083.1 added to model
New gene 7084.1 added to model
New gene 1854.1 added to model
New gene 3704.1 added to model
New gene 10682.1 added to model
New gene 1892.1 added to model
New gene 549.1 added to model
New gene 11001.1 added to model
New gene 28231.1 added to model
New gene 53919.1 added to model
New gene 10257.1 added to model
New gene 28232.1 added to model
New gene 2109.2 added to model
New gene 2108.1 added to model
New gene 2109.1 added to model
New gene 2110.1 added to model
New gene 55500.1 added to model
New gene 55224.1 added to model
New gene 8790.1 added to model

New gene 51086.1 added to model
New gene 2181.1 added to model
New gene 2182.1 added to model
New gene 2180.1 added to model
New gene 2181.2 added to model
New gene 51703.1 added to model
New gene 81616.1 added to model
New gene 23305.1 added to model
New gene 2182.2 added to model
New gene 116285.1 added to model
New gene 5167.1 added to model
New gene 5169.1 added to model
New gene 6785.1 added to model
New gene 79071.1 added to model
New gene 60481.1 added to model
New gene 54898.1 added to model
New gene 1579.1 added to model
New gene 1962.1 added to model
New gene 2194.1 added to model
New gene 376497.2 added to model
New gene 10999.1 added to model
New gene 376497.1 added to model
New gene 11000.1 added to model
New gene 226.2 added to model
New gene 229.1 added to model
New gene 226.3 added to model
New gene 230.1 added to model
New gene 226.1 added to model
New gene 2203.1 added to model
New gene 5210.1 added to model
New gene 5207.1 added to model
New gene 5209.1 added to model
New gene 5208.1 added to model
New gene 8789.1 added to model
New gene 2235.1 added to model
New gene 2235.2 added to model
New gene 10840.1 added to model
New gene 79901.1 added to model
New gene 197258.1 added to model
New gene 125061.1 added to model
New gene 1719.1 added to model
New gene 2356.1 added to model
New gene 29988.1 added to model
New gene 6514.1 added to model
New gene 155184.1 added to model
New gene 6518.1 added to model
New gene 66035.1 added to model
New gene 160428.1 added to model
New gene 25902.1 added to model
New gene 4522.1 added to model
New gene 2519.1 added to model
New gene 2517.1 added to model
New gene 2184.1 added to model
New gene 2271.1 added to model
New gene 2523.1 added to model
New gene 2525.1 added to model
New gene 10690.1 added to model
New gene 8703.1 added to model
New gene 8704.2 added to model

New gene 8704.1 added to model
New gene 2683.1 added to model
New gene 9334.1 added to model
New gene 2820.1 added to model
New gene 5832.1 added to model
New gene 9563.1 added to model
New gene 2539.1 added to model
New gene 2542.1 added to model
New gene 2593.1 added to model
New gene 2593.2 added to model
New gene 9514.1 added to model
New gene 5476.1 added to model
New gene 2720.1 added to model
New gene 2588.1 added to model
New gene 4758.1 added to model
New gene 2581.1 added to model
New gene 2583.1 added to model
New gene 55790.1 added to model
New gene 55454.1 added to model
New gene 79586.1 added to model
New gene 22856.1 added to model
New gene 337876.1 added to model
New gene 26290.1 added to model
New gene 79695.1 added to model
New gene 2589.1 added to model
New gene 50614.1 added to model
New gene 8693.1 added to model
New gene 55568.2 added to model
New gene 114805.1 added to model
New gene 11226.1 added to model
New gene 117248.1 added to model
New gene 11227.1 added to model
New gene 55568.1 added to model
New gene 2590.1 added to model
New gene 51809.1 added to model
New gene 79623.1 added to model
New gene 63917.1 added to model
New gene 2591.1 added to model
New gene 81031.1 added to model
New gene 126792.1 added to model
New gene 11285.1 added to model
New gene 8972.1 added to model
New gene 2618.1 added to model
New gene 2618.2 added to model
New gene 175.1 added to model
New gene 2629.2 added to model
New gene 2629.3 added to model
New gene 2629.4 added to model
New gene 2629.5 added to model
New gene 2629.1 added to model
New gene 26301.1 added to model
New gene 4329.1 added to model
New gene 7915.1 added to model
New gene 7915.2 added to model
New gene 275.1 added to model
New gene 2731.1 added to model
New gene 2653.1 added to model
New gene 2651.1 added to model
New gene 55343.1 added to model
New gene 7264.1 added to model

New gene 8836.1 added to model

New gene 79017.1 added to model

New gene 8908.1 added to model
New gene 2998.1 added to model
New gene 2992.1 added to model
New gene 2997.1 added to model

New gene 2687.1 added to model

New gene 6472.1 added to model
New gene 6470.1 added to model

New gene 6470.2 added to model

New gene 2717.1 added to model

New gene 2632.1 added to model

New gene 2990.1 added to model

New gene 8372.1 added to model

New gene 26035.1 added to model

New gene 54480.1 added to model

New gene 2131.1 added to model
New gene 2132.1 added to model
New gene 2132.2 added to model

New gene 27087.2 added to model
New gene 135152.1 added to model
New gene 27087.1 added to model
New gene 26229.1 added to model

New gene 4669.1 added to model

New gene 64579.1 added to model
New gene 3340.1 added to model
New gene 9348.1 added to model
New gene 8509.1 added to model

New gene 2137.1 added to model
New gene 2135.1 added to model

New gene 2134.1 added to model

New gene 56606.1 added to model
New gene 154091.1 added to model
New gene 11182.1 added to model
New gene 56606.2 added to model
New gene 144195.1 added to model

New gene 6523.1 added to model

New gene 178.4 added to model
New gene 178.5 added to model
New gene 178.1 added to model
New gene 178.3 added to model
New gene 178.2 added to model
New gene 178.6 added to model

New gene 5834.1 added to model
New gene 5837.1 added to model
New gene 5836.1 added to model

New gene 2729.1 added to model
New gene 2730.1 added to model

New gene 2747.1 added to model
New gene 2746.1 added to model

New gene 10841.1 added to model
New gene 10841.2 added to model

New gene 2744.1 added to model
New gene 27165.2 added to model
New gene 27165.1 added to model

New gene 83733.1 added to model
New gene 79751.1 added to model

New gene 2639.1 added to model
New gene 2639.2 added to model

New gene 57084.1 added to model

New gene 246213.1 added to model
New gene 57030.1 added to model
New gene 54363.1 added to model
New gene 51179.2 added to model
New gene 51179.1 added to model
New gene 2628.1 added to model
New gene 9380.1 added to model
New gene 2710.2 added to model
New gene 2712.1 added to model
New gene 2710.1 added to model
New gene 2713.1 added to model
New gene 3029.1 added to model
New gene 6536.1 added to model
New gene 6536.2 added to model
New gene 5226.1 added to model
New gene 27232.1 added to model
New gene 57678.1 added to model
New gene 2936.1 added to model
New gene 7001.3 added to model
New gene 5052.3 added to model
New gene 2877.1 added to model
New gene 2876.2 added to model
New gene 5052.2 added to model
New gene 2876.1 added to model
New gene 5052.1 added to model
New gene 7001.1 added to model
New gene 2879.1 added to model
New gene 7001.2 added to model
New gene 2878.1 added to model
New gene 257202.1 added to model
New gene 2882.1 added to model
New gene 10935.1 added to model
New gene 10935.2 added to model
New gene 2937.1 added to model
New gene 2679.1 added to model
New gene 2678.1 added to model
New gene 2678.3 added to model
New gene 2678.2 added to model
New gene 2977.1 added to model
New gene 2983.1 added to model
New gene 4882.2 added to model
New gene 2982.1 added to model
New gene 2974.1 added to model
New gene 2986.1 added to model
New gene 4882.1 added to model
New gene 2984.1 added to model
New gene 4881.1 added to model
New gene 3000.1 added to model
New gene 9615.1 added to model
New gene 763.1 added to model
New gene 11238.1 added to model
New gene 53905.1 added to model
New gene 50506.1 added to model
New gene 53905.2 added to model
New gene 343.1 added to model
New gene 3028.1 added to model
New gene 3033.1 added to model
New gene 3038.2 added to model
New gene 3036.1 added to model
New gene 3038.1 added to model
New gene 3037.1 added to model

New gene 27235.1 added to model
New gene 6522.1 added to model
New gene 83697.1 added to model
New gene 6521.1 added to model
New gene 6508.2 added to model
New gene 6508.1 added to model
New gene 2645.1 added to model
New gene 3099.1 added to model
New gene 3098.3 added to model
New gene 2645.2 added to model
New gene 80201.1 added to model
New gene 3098.2 added to model
New gene 2645.3 added to model
New gene 3098.1 added to model
New gene 3098.4 added to model
New gene 3101.1 added to model
New gene 3098.5 added to model
New gene 3081.1 added to model
New gene 11112.1 added to model
New gene 3067.1 added to model
New gene 495.1 added to model
New gene 496.1 added to model
New gene 8942.1 added to model
New gene 3157.1 added to model
New gene 3157.2 added to model
New gene 3158.1 added to model
New gene 3155.1 added to model
New gene 54511.1 added to model
New gene 3162.1 added to model
New gene 3163.1 added to model
New gene 26062.1 added to model
New gene 197257.1 added to model
New gene 197257.2 added to model
New gene 6448.1 added to model
New gene 3290.2 added to model
New gene 3290.1 added to model
New gene 3291.1 added to model
New gene 3292.1 added to model
New gene 7923.1 added to model
New gene 3294.1 added to model
New gene 51478.1 added to model
New gene 3283.1 added to model
New gene 3284.1 added to model
New gene 80270.1 added to model
New gene 57026.1 added to model
New gene 3421.2 added to model
New gene 3420.3 added to model
New gene 3419.1 added to model
New gene 3420.1 added to model
New gene 3421.1 added to model
New gene 3420.2 added to model
New gene 3417.1 added to model
New gene 3418.1 added to model
New gene 7173.4 added to model
New gene 7173.1 added to model
New gene 7173.3 added to model
New gene 7173.2 added to model
New gene 7173.5 added to model
New gene 3425.1 added to model

New gene 587.1 added to model
New gene 8501.1 added to model
New gene 55586.1 added to model
New gene 114134.1 added to model
New gene 6526.1 added to model
New gene 3422.1 added to model
New gene 91734.1 added to model
New gene 160728.1 added to model
New gene 8802.1 added to model
New gene 8801.1 added to model
New gene 8803.1 added to model
New gene 6560.1 added to model
New gene 10723.1 added to model
New gene 9990.1 added to model
New gene 57468.1 added to model
New gene 3795.1 added to model
New gene 3795.2 added to model
New gene 84679.1 added to model
New gene 23315.1 added to model
New gene 8564.1 added to model
New gene 3938.1 added to model
New gene 53.1 added to model
New gene 3931.1 added to model
New gene 387775.1 added to model
New gene 124637.1 added to model
New gene 366.1 added to model
New gene 4047.1 added to model
New gene 5321.1 added to model
New gene 1178.1 added to model
New gene 29124.1 added to model
New gene 51268.1 added to model
New gene 4023.1 added to model
New gene 3990.1 added to model
New gene 1056.1 added to model
New gene 80339.1 added to model
New gene 11343.1 added to model
New gene 11343.2 added to model
New gene 50487.1 added to model
New gene 9227.1 added to model
New gene 6309.1 added to model
New gene 4048.1 added to model
New gene 4056.1 added to model
New gene 4259.1 added to model
New gene 4056.2 added to model
New gene 4258.1 added to model
New gene 2954.1 added to model
New gene 2954.3 added to model
New gene 2954.2 added to model
New gene 56922.1 added to model
New gene 64087.1 added to model
New gene 23417.1 added to model
New gene 4357.1 added to model
New gene 4191.1 added to model
New gene 4190.1 added to model
New gene 4200.1 added to model
New gene 4199.1 added to model
New gene 10873.1 added to model

New gene 3620.1 added to model

New gene 1557.1 added to model
New gene 1543.1 added to model
New gene 1545.1 added to model
New gene 1544.1 added to model

New gene 4143.1 added to model
New gene 27430.2 added to model
New gene 4144.1 added to model
New gene 27430.1 added to model

New gene 4548.1 added to model

New gene 4598.1 added to model

New gene 3635.1 added to model
New gene 8867.2 added to model
New gene 3636.1 added to model
New gene 27124.2 added to model
New gene 8867.1 added to model
New gene 27124.1 added to model
New gene 3633.1 added to model
New gene 56623.1 added to model
New gene 3632.1 added to model

New gene 3628.1 added to model

New gene 3706.1 added to model
New gene 80271.1 added to model
New gene 3707.1 added to model

New gene 51477.1 added to model

New gene 3631.2 added to model
New gene 3631.1 added to model
New gene 8821.1 added to model

New gene 2595.1 added to model

New gene 84693.1 added to model

New gene 4594.1 added to model

New gene 116255.1 added to model
New gene 80168.1 added to model

New gene 4507.1 added to model

New gene 10797.1 added to model

New gene 56913.1 added to model

New gene 443.1 added to model
New gene 91703.1 added to model

New gene 4668.1 added to model

New gene 9498.1 added to model
New gene 57282.1 added to model

New gene 6528.1 added to model

New gene 481.1 added to model
New gene 478.1 added to model
New gene 477.1 added to model
New gene 23439.1 added to model
New gene 483.1 added to model
New gene 476.1 added to model
New gene 480.1 added to model
New gene 482.1 added to model

New gene 6548.1 added to model
New gene 6550.1 added to model
New gene 6549.1 added to model

New gene 84735.1 added to model
New gene 55748.1 added to model

New gene 6559.1 added to model

New gene 123041.2 added to model
New gene 57419.1 added to model
New gene 9187.1 added to model
New gene 123041.3 added to model

New gene 25769.1 added to model
New gene 123041.1 added to model
New gene 124583.1 added to model
New gene 79077.1 added to model
New gene 9583.1 added to model
New gene 1841.1 added to model
New gene 4832.1 added to model
New gene 4831.1 added to model
New gene 4830.1 added to model
New gene 10201.1 added to model
New gene 29922.2 added to model
New gene 29922.1 added to model
New gene 4830.2 added to model
New gene 4833.1 added to model
New gene 57127.1 added to model
New gene 6005.1 added to model
New gene 6557.1 added to model
New gene 6558.1 added to model
New gene 349565.1 added to model
New gene 64802.1 added to model
New gene 23057.1 added to model
New gene 23057.2 added to model
New gene 10135.1 added to model
New gene 4837.1 added to model
New gene 5409.1 added to model
New gene 4846.1 added to model
New gene 201288.1 added to model
New gene 4842.1 added to model
New gene 4843.2 added to model
New gene 4843.1 added to model
New gene 645740.1 added to model
New gene 4860.1 added to model
New gene 6580.1 added to model
New gene 55808.1 added to model
New gene 56953.1 added to model
New gene 4907.1 added to model
New gene 30833.1 added to model
New gene 6476.1 added to model
New gene 5009.1 added to model
New gene 5019.1 added to model
New gene 64064.1 added to model
New gene 1629.1 added to model
New gene 594.1 added to model
New gene 593.1 added to model
New gene 594.2 added to model
New gene 26873.1 added to model
New gene 4942.1 added to model
New gene 7372.1 added to model
New gene 1836.1 added to model
New gene 10861.1 added to model
New gene 10861.3 added to model
New gene 10861.2 added to model
New gene 1811.1 added to model
New gene 1583.1 added to model
New gene 1584.1 added to model
New gene 1585.1 added to model
New gene 1586.1 added to model
New gene 1588.1 added to model

New gene 1588.2 added to model
New gene 1576.1 added to model
New gene 1589.1 added to model
New gene 1593.1 added to model
New gene 1562.1 added to model
New gene 1559.1 added to model
New gene 51302.1 added to model
New gene 64816.1 added to model
New gene 64816.3 added to model
New gene 64816.2 added to model
New gene 1551.1 added to model
New gene 10858.1 added to model
New gene 1572.1 added to model
New gene 66002.1 added to model
New gene 4051.1 added to model
New gene 8529.1 added to model
New gene 11283.1 added to model
New gene 9420.1 added to model
New gene 1582.1 added to model
New gene 5831.1 added to model
New gene 5831.2 added to model
New gene 5051.1 added to model
New gene 5049.1 added to model
New gene 5050.1 added to model
New gene 5048.1 added to model
New gene 7941.1 added to model
New gene 347734.1 added to model
New gene 57194.1 added to model
New gene 5338.1 added to model
New gene 5337.1 added to model
New gene 130013.1 added to model
New gene 5091.1 added to model
New gene 5091.2 added to model
New gene 5244.1 added to model
New gene 5244.3 added to model
New gene 5244.2 added to model
New gene 19.1 added to model

New gene 5139.1 added to model
New gene 5142.1 added to model
New gene 5151.3 added to model
New gene 5153.1 added to model
New gene 5150.2 added to model
New gene 5143.1 added to model
New gene 5150.1 added to model
New gene 5137.1 added to model
New gene 5144.1 added to model
New gene 5136.2 added to model
New gene 5140.2 added to model
New gene 5151.2 added to model
New gene 10846.1 added to model
New gene 5151.5 added to model
New gene 5140.1 added to model
New gene 5141.1 added to model
New gene 5138.1 added to model
New gene 5136.1 added to model
New gene 5151.4 added to model
New gene 5151.1 added to model
New gene 27115.1 added to model
New gene 50940.1 added to model
New gene 8622.1 added to model

New gene 5146.1 added to model
New gene 5152.17 added to model
New gene 5152.6 added to model
New gene 5152.11 added to model
New gene 5152.2 added to model
New gene 8654.2 added to model
New gene 5152.10 added to model
New gene 5145.1 added to model
New gene 5158.1 added to model
New gene 5149.1 added to model
New gene 5152.12 added to model
New gene 5152.15 added to model
New gene 5152.5 added to model
New gene 5152.20 added to model
New gene 5152.19 added to model
New gene 5152.16 added to model
New gene 8654.3 added to model
New gene 5152.14 added to model
New gene 5152.13 added to model
New gene 5152.7 added to model
New gene 5152.3 added to model
New gene 8654.1 added to model
New gene 5152.18 added to model
New gene 5147.1 added to model
New gene 5148.1 added to model
New gene 5152.4 added to model

New gene 5152.1 added to model

New gene 5161.1 added to model
New gene 5162.1 added to model
New gene 1737.1 added to model
New gene 5160.1 added to model

New gene 55163.1 added to model

New gene 10396.1 added to model

New gene 5105.1 added to model

New gene 5106.1 added to model

New gene 8310.1 added to model

New gene 5833.1 added to model

New gene 10400.2 added to model
New gene 10400.1 added to model
New gene 10400.3 added to model

New gene 26227.1 added to model

New gene 5730.1 added to model
New gene 27306.1 added to model

New gene 80142.4 added to model
New gene 80142.2 added to model
New gene 9536.1 added to model
New gene 80142.1 added to model
New gene 9536.2 added to model
New gene 80142.3 added to model

New gene 5740.1 added to model

New gene 114971.1 added to model

New gene 9489.1 added to model

New gene 5743.1 added to model
New gene 5742.1 added to model

New gene 6898.1 added to model

New gene 5053.1 added to model

New gene 5264.1 added to model

New gene 5728.1 added to model

New gene 8871.1 added to model

New gene 8394.1 added to model
New gene 23396.1 added to model

New gene 8395.1 added to model

New gene 55361.1 added to model
New gene 5297.1 added to model
New gene 5298.1 added to model

New gene 5291.1 added to model
New gene 5295.3 added to model
New gene 5293.1 added to model
New gene 8503.1 added to model
New gene 5296.1 added to model
New gene 5290.1 added to model
New gene 5295.1 added to model
New gene 5295.2 added to model
New gene 10870.1 added to model
New gene 5294.1 added to model
New gene 23533.1 added to model

New gene 4952.1 added to model
New gene 4952.2 added to model

New gene 23236.2 added to model
New gene 5336.1 added to model
New gene 9651.1 added to model
New gene 113026.1 added to model
New gene 89869.1 added to model
New gene 84812.1 added to model
New gene 5330.1 added to model
New gene 5335.1 added to model
New gene 51196.1 added to model
New gene 5333.1 added to model
New gene 5332.2 added to model
New gene 5331.1 added to model
New gene 5335.2 added to model
New gene 5334.1 added to model
New gene 5332.1 added to model
New gene 257068.1 added to model
New gene 23236.1 added to model
New gene 23007.1 added to model

New gene 5287.1 added to model
New gene 5286.1 added to model
New gene 5288.1 added to model

New gene 200576.2 added to model
New gene 8396.1 added to model
New gene 200576.3 added to model
New gene 79837.1 added to model
New gene 8396.2 added to model
New gene 5305.1 added to model
New gene 200576.1 added to model

New gene 5289.1 added to model

New gene 8398.1 added to model
New gene 5320.1 added to model
New gene 8398.2 added to model
New gene 81579.1 added to model
New gene 5322.1 added to model
New gene 64600.1 added to model
New gene 100137049.1 added to model
New gene 123745.1 added to model

New gene 5319.1 added to model
New gene 26279.1 added to model
New gene 8399.1 added to model
New gene 30814.1 added to model

New gene 10654.1 added to model

New gene 8876.1 added to model
New gene 8875.2 added to model
New gene 55350.3 added to model
New gene 55350.2 added to model
New gene 8875.1 added to model

New gene 55350.1 added to model
New gene 27068.4 added to model
New gene 27068.1 added to model
New gene 27068.3 added to model
New gene 27068.2 added to model
New gene 8612.1 added to model
New gene 8611.1 added to model
New gene 8613.1 added to model
New gene 8611.2 added to model
New gene 5498.1 added to model
New gene 8288.1 added to model
New gene 9588.1 added to model
New gene 4353.1 added to model
New gene 6820.2 added to model
New gene 5625.1 added to model
New gene 6578.1 added to model
New gene 23761.1 added to model
New gene 9791.1 added to model
New gene 81490.1 added to model
New gene 10965.1 added to model
New gene 5805.1 added to model
New gene 6303.1 added to model
New gene 112483.1 added to model
New gene 8566.1 added to model
New gene 7378.2 added to model
New gene 151531.1 added to model
New gene 7378.1 added to model
New gene 2944.1 added to model
New gene 2944.2 added to model
New gene 5959.1 added to model
New gene 8608.1 added to model
New gene 157506.1 added to model
New gene 112724.1 added to model
New gene 145226.1 added to model
New gene 51109.1 added to model
New gene 195814.1 added to model
New gene 57665.1 added to model
New gene 50700.1 added to model
New gene 8228.1 added to model
New gene 113278.1 added to model
New gene 54981.1 added to model
New gene 6484.1 added to model
New gene 6482.1 added to model
New gene 6483.1 added to model
New gene 6482.2 added to model
New gene 10090.1 added to model
New gene 9653.1 added to model
New gene 3423.1 added to model
New gene 3423.2 added to model
New gene 9957.1 added to model
New gene 9951.1 added to model
New gene 222537.1 added to model
New gene 9956.1 added to model
New gene 9955.1 added to model
New gene 9953.1 added to model
New gene 64711.1 added to model
New gene 113189.1 added to model
New gene 50515.1 added to model
New gene 166012.1 added to model

New gene 55501.1 added to model
New gene 411.2 added to model
New gene 411.1 added to model
New gene 23563.2 added to model
New gene 9435.1 added to model
New gene 23563.1 added to model
New gene 10164.1 added to model
New gene 4166.1 added to model
New gene 8534.1 added to model
New gene 9469.1 added to model
New gene 56548.1 added to model
New gene 266722.1 added to model
New gene 9394.1 added to model
New gene 90161.2 added to model
New gene 90161.1 added to model
New gene 2799.1 added to model
New gene 10157.1 added to model
New gene 118881.1 added to model
New gene 3176.1 added to model
New gene 1757.1 added to model
New gene 81537.1 added to model
New gene 6652.1 added to model
New gene 6342.1 added to model
New gene 9056.1 added to model
New gene 10558.1 added to model
New gene 9517.1 added to model
New gene 55304.1 added to model
New gene 2098.1 added to model
New gene 8879.1 added to model
New gene 8869.1 added to model
New gene 56848.1 added to model
New gene 8877.1 added to model
New gene 130752.1 added to model
New gene 55512.1 added to model
New gene 55512.2 added to model
New gene 339221.1 added to model
New gene 55627.1 added to model
New gene 6609.1 added to model
New gene 6610.1 added to model
New gene 259230.1 added to model
New gene 115111.1 added to model
New gene 115019.2 added to model
New gene 115111.2 added to model
New gene 116369.2 added to model
New gene 284129.1 added to model
New gene 116369.1 added to model
New gene 115019.1 added to model
New gene 26266.1 added to model
New gene 6646.1 added to model
New gene 6649.1 added to model
New gene 6648.1 added to model
New gene 6647.1 added to model
New gene 6697.1 added to model
New gene 6611.1 added to model
New gene 6723.1 added to model
New gene 6713.1 added to model
New gene 2222.1 added to model
New gene 6715.1 added to model

New gene 6716.1 added to model
New gene 15.1 added to model
New gene 6532.1 added to model
New gene 6487.6 added to model
New gene 6487.11 added to model
New gene 6487.5 added to model
New gene 6487.7 added to model
New gene 6487.9 added to model
New gene 6487.1 added to model
New gene 6487.8 added to model
New gene 6487.4 added to model
New gene 6487.3 added to model
New gene 6487.10 added to model
New gene 6487.2 added to model
New gene 10402.1 added to model
New gene 10610.1 added to model
New gene 256435.1 added to model
New gene 30815.1 added to model
New gene 81849.1 added to model
New gene 6489.1 added to model
New gene 29906.1 added to model
New gene 412.1 added to model
New gene 6389.1 added to model
New gene 6392.1 added to model
New gene 6391.1 added to model
New gene 6390.1 added to model
New gene 6821.1 added to model
New gene 6533.1 added to model
New gene 5092.1 added to model
New gene 5092.2 added to model
New gene 23530.2 added to model
New gene 23530.1 added to model
New gene 79178.1 added to model
New gene 6567.1 added to model
New gene 1890.1 added to model
New gene 55217.1 added to model
New gene 7296.3 added to model
New gene 7296.1 added to model
New gene 7296.4 added to model
New gene 7296.2 added to model
New gene 80162.1 added to model
New gene 11181.1 added to model
New gene 7166.1 added to model
New gene 121278.1 added to model
New gene 6999.1 added to model
New gene 169355.1 added to model
New gene 6561.1 added to model
New gene 6916.1 added to model
New gene 7054.1 added to model
New gene 7054.3 added to model
New gene 7054.2 added to model
New gene 7306.1 added to model
New gene 10020.1 added to model
New gene 29880.1 added to model
New gene 7355.1 added to model
New gene 7358.1 added to model
New gene 23169.1 added to model
New gene 80146.1 added to model

New gene 5168.1 added to model
New gene 84912.1 added to model
New gene 3906.1 added to model
New gene 7357.1 added to model
New gene 11046.1 added to model
New gene 54576.1 added to model
New gene 54575.1 added to model
New gene 54578.1 added to model
New gene 54579.1 added to model
New gene 54600.1 added to model
New gene 54658.1 added to model
New gene 54659.1 added to model
New gene 54577.1 added to model
New gene 54657.1 added to model
New gene 7364.1 added to model
New gene 54490.1 added to model
New gene 7367.1 added to model
New gene 10720.1 added to model
New gene 7363.1 added to model
New gene 7365.1 added to model
New gene 7366.1 added to model
New gene 54963.1 added to model
New gene 7498.1 added to model
New gene 9942.1 added to model
New gene 64131.1 added to model
New gene 64132.1 added to model
New gene 51181.1 added to model
New gene 64077.1 added to model
New gene 5464.1 added to model
New gene 10724.1 added to model
New gene 1356.1 added to model
New gene 2512.1 added to model
New gene 2495.1 added to model
New gene 94033.1 added to model
New gene 1727.1 added to model
New gene 51706.1 added to model
New gene 51700.1 added to model
New gene 10587.1 added to model
New gene 80347.1 added to model
New gene 22978.1 added to model
New gene 84618.1 added to model
New gene 51251.1 added to model
New gene 93034.1 added to model
New gene 100526794.1 added to model
New gene 3251.1 added to model
New gene 353.1 added to model
New gene 56954.1 added to model
New gene 5313.1 added to model
New gene 92086.1 added to model
New gene 728441.1 added to model
New gene 102724197.1 added to model
New gene 2686.1 added to model
New gene 124975.1 added to model
New gene 91227.1 added to model
New gene 5211.1 added to model
New gene 1491.1 added to model
New gene 2819.1 added to model
New gene 29926.1 added to model
New gene 29925.1 added to model

New gene 875.1 added to model
New gene 102724560.1 added to model
New gene 249.1 added to model
New gene 22934.1 added to model
New gene 51292.1 added to model
New gene 2766.1 added to model
New gene 57571.1 added to model
New gene 8833.1 added to model
New gene 11332.1 added to model
New gene 5538.1 added to model
New gene 122970.1 added to model
New gene 641371.1 added to model
New gene 9374.1 added to model
New gene 55825.1 added to model
New gene 51102.1 added to model
New gene 37.1 added to model
New gene 33.1 added to model
New gene 132158.1 added to model
New gene 641649.1 added to model
New gene 93100.1 added to model
New gene 23475.1 added to model
New gene 50484.1 added to model
New gene 6240.1 added to model
New gene 6241.1 added to model
New gene 3156.1 added to model
New gene 79966.1 added to model
New gene 10588.1 added to model
New gene 84890.1 added to model
New gene 79646.1 added to model
New gene 80025.1 added to model
New gene 53354.1 added to model
New gene 55229.1 added to model
New gene 83594.1 added to model
New gene 7263.1 added to model
New gene 26275.1 added to model
New gene 29920.1 added to model
New gene 7389.1 added to model
New gene 1595.1 added to model
New gene 130367.1 added to model
New gene 10478.1 added to model
New gene 23443.1 added to model
New gene 64240.1 added to model
New gene 64241.1 added to model
New gene 284111.1 added to model
New gene 8435.1 added to model
New gene 3988.1 added to model
New gene 1118.1 added to model
New gene 27159.1 added to model
New gene 771.1 added to model
New gene 760.1 added to model
New gene 768.1 added to model
New gene 23632.1 added to model
New gene 765.1 added to model
New gene 759.1 added to model
New gene 762.1 added to model
New gene 766.1 added to model
New gene 767.1 added to model
New gene 377677.1 added to model

New gene 10057.1 added to model
New gene 6556.1 added to model
New gene 6568.1 added to model
New gene 7779.1 added to model
New gene 54020.1 added to model
New gene 215.1 added to model
New gene 5825.1 added to model
New gene 641372.1 added to model
New gene 9045.1 added to model
New gene 4017.1 added to model
New gene 84105.1 added to model
New gene 25830.1 added to model
New gene 84569.1 added to model
New gene 4025.1 added to model
New gene 54995.1 added to model
New gene 93492.1 added to model
New gene 1632.1 added to model
New gene 10455.1 added to model
New gene 10005.1 added to model
New gene 1267.1 added to model
New gene 10249.1 added to model
New gene 1558.1 added to model
New gene 1565.1 added to model
New gene 1548.1 added to model
New gene 1580.1 added to model
New gene 1555.1 added to model
New gene 1577.1 added to model
New gene 1549.1 added to model
New gene 1573.1 added to model
New gene 1553.1 added to model
New gene 199974.1 added to model
New gene 260293.1 added to model
New gene 29785.1 added to model
New gene 57834.1 added to model
New gene 1215.1 added to model
New gene 1357.1 added to model
New gene 1358.1 added to model
New gene 57094.1 added to model
New gene 93979.1 added to model
New gene 7177.1 added to model
New gene 64499.1 added to model
New gene 23430.1 added to model
New gene 1636.1 added to model
New gene 9365.1 added to model
New gene 9331.1 added to model
New gene 7368.1 added to model
New gene 5315.1 added to model
New gene 26063.1 added to model
New gene 1891.1 added to model
New gene 1666.1 added to model
New gene 874.1 added to model
New gene 10901.1 added to model
New gene 126410.1 added to model
New gene 2053.1 added to model
New gene 8897.1 added to model
New gene 8897.3 added to model
New gene 8897.2 added to model

New gene 8898.1 added to model
New gene 2880.1 added to model
New gene 9152.1 added to model
New gene 9497.1 added to model
New gene 115584.1 added to model
New gene 6574.1 added to model
New gene 6575.1 added to model
New gene 142680.1 added to model
New gene 6534.1 added to model
New gene 3293.1 added to model
New gene 1622.1 added to model
New gene 225.1 added to model
New gene 28965.1 added to model
New gene 23205.1 added to model
New gene 26061.1 added to model
New gene 54716.1 added to model
New gene 6564.1 added to model
New gene 113235.1 added to model
New gene 1200.1 added to model
New gene 2168.1 added to model
New gene 51056.1 added to model
New gene 9390.1 added to model
New gene 5184.1 added to model
New gene 1594.1 added to model
New gene 4891.1 added to model
New gene 30061.1 added to model
New gene 248.1 added to model
New gene 4524.1 added to model
New gene 65263.1 added to model
New gene 25796.1 added to model
New gene 28982.1 added to model
New gene 6120.1 added to model
New gene 6120.2 added to model
New gene 10864.1 added to model
New gene 9356.1 added to model
New gene 9376.1 added to model
New gene 348932.1 added to model
New gene 120103.1 added to model
New gene 1080.1 added to model
New gene 85320.1 added to model
New gene 222962.1 added to model
New gene 10351.1 added to model
New gene 9429.1 added to model
New gene 55867.1 added to model
New gene 360.1 added to model
New gene 364.1 added to model
New gene 89872.1 added to model
New gene 21.1 added to model
New gene 24.1 added to model
New gene 10057.2 added to model
New gene 125206.1 added to model
New gene 200010.1 added to model
New gene 6524.1 added to model
New gene 159963.1 added to model

New gene 79581.1 added to model
New gene 55065.1 added to model
New gene 3764.1 added to model
New gene 6833.1 added to model
New gene 10060.1 added to model
New gene 3767.1 added to model
New gene 5950.1 added to model
New gene 64220.1 added to model
New gene 5947.1 added to model
New gene 5948.1 added to model
New gene 949.1 added to model
New gene 29881.1 added to model
New gene 2350.1 added to model
New gene 3248.1 added to model
New gene 166929.1 added to model
New gene 56261.1 added to model
New gene 3658.1 added to model
New gene 122481.1 added to model
New gene 203.1 added to model
New gene 159.1 added to model
New gene 122622.1 added to model
New gene 122622.2 added to model
New gene 11212.1 added to model
New gene 383.1 added to model
New gene 1371.1 added to model
New gene 1503.1 added to model
New gene 56474.1 added to model
New gene 1491.2 added to model
New gene 2987.1 added to model
New gene 5860.1 added to model
New gene 9453.1 added to model
New gene 2023.1 added to model
New gene 2027.1 added to model
New gene 2027.2 added to model
New gene 2026.1 added to model
New gene 9843.1 added to model
New gene 80308.1 added to model
New gene 80308.2 added to model
New gene 7360.1 added to model
New gene 7360.2 added to model
New gene 2597.1 added to model
New gene 26330.1 added to model
New gene 2673.1 added to model
New gene 9945.1 added to model
New gene 2752.1 added to model
New gene 51557.1 added to model
New gene 1800.1 added to model
New gene 2762.1 added to model
New gene 2643.1 added to model
New gene 761.1 added to model
New gene 766.2 added to model
New gene 771.2 added to model
New gene 358.1 added to model
New gene 361.1 added to model
New gene 4284.1 added to model
New gene 359.1 added to model
New gene 362.1 added to model
New gene 3145.1 added to model

New gene 586.1 added to model
New gene 3614.1 added to model
New gene 3615.1 added to model
New gene 3614.2 added to model
New gene 682.1 added to model
New gene 29926.2 added to model
New gene 29925.2 added to model
New gene 4351.1 added to model
New gene 100287639.1 added to model
New gene 441024.1 added to model
New gene 65220.1 added to model
New gene 389015.1 added to model
New gene 6553.1 added to model
New gene 2821.1 added to model
New gene 5230.1 added to model
New gene 375056.1 added to model
New gene 5232.1 added to model
New gene 5236.1 added to model
New gene 55276.1 added to model
New gene 5372.1 added to model
New gene 5373.1 added to model
New gene 80025.2 added to model
New gene 53354.3 added to model
New gene 53354.2 added to model
New gene 80025.3 added to model
New gene 80025.4 added to model
New gene 210.1 added to model
New gene 210.2 added to model
New gene 60490.1 added to model
New gene 79717.1 added to model
New gene 58510.1 added to model
New gene 153201.1 added to model
New gene 221823.2 added to model
New gene 5631.1 added to model
New gene 221823.1 added to model
New gene 5634.1 added to model
New gene 29968.1 added to model
New gene 29968.2 added to model
New gene 8781.1 added to model
New gene 5723.1 added to model
New gene 55312.1 added to model
New gene 6888.1 added to model
New gene 7086.1 added to model
New gene 84076.1 added to model
New gene 8277.1 added to model
New gene 27010.1 added to model
New gene 7167.1 added to model
New gene 286016.1 added to model
New gene 2582.1 added to model
New gene 2582.2 added to model
New gene 6675.1 added to model
New gene 91373.1 added to model
New gene 7390.1 added to model
New gene 6563.1 added to model
New gene 8170.1 added to model
New gene 374569.1 added to model
New gene 100507855.1 added to model
New gene 31.5 added to model

New gene 31.4 added to model
New gene 31.2 added to model
New gene 31.3 added to model
New gene 31.1 added to model
New gene 93034.2 added to model
New gene 55191.1 added to model
New gene 11164.1 added to model
New gene 64080.1 added to model
New gene 132.1 added to model
New gene 132.2 added to model
New gene 112611.1 added to model
New gene 98.1 added to model
New gene 97.2 added to model
New gene 97.1 added to model
New gene 51005.1 added to model
New gene 471.1 added to model
New gene 435.1 added to model
New gene 171425.1 added to model
New gene 171425.2 added to model
New gene 132789.1 added to model
New gene 10007.1 added to model
New gene 2584.1 added to model
New gene 2585.2 added to model
New gene 2585.1 added to model
New gene 2592.1 added to model
New gene 2592.3 added to model
New gene 2592.2 added to model
New gene 5471.1 added to model
New gene 84264.2 added to model
New gene 84264.1 added to model
New gene 3034.1 added to model
New gene 144193.1 added to model
New gene 2739.1 added to model
New gene 2548.1 added to model
New gene 3612.1 added to model
New gene 3613.1 added to model
New gene 8776.1 added to model
New gene 2978.1 added to model
New gene 4953.1 added to model
New gene 5214.1 added to model
New gene 5211.2 added to model
New gene 5213.1 added to model
New gene 10050.1 added to model
New gene 10786.1 added to model
New gene 10246.1 added to model
New gene 6569.1 added to model
New gene 10568.1 added to model
New gene 5198.1 added to model
New gene 5315.2 added to model
New gene 5313.2 added to model
New gene 5315.3 added to model
New gene 113675.1 added to model
New gene 7298.1 added to model
New gene 131669.1 added to model
New gene 5973.1 added to model
New gene 1635.1 added to model
New gene 286297.1 added to model
New gene 10560.1 added to model

```
New gene 191.1 added to model
New gene 10768.2 added to model
New gene 10768.1 added to model
New gene 51660.1 added to model
New gene 25874.1 added to model
New gene 5205.1 added to model
New gene 57198.1 added to model
New gene 23250.1 added to model
New gene 286410.1 added to model
New gene 5243.1 added to model
New gene 55856.1 added to model
New gene 7350.1 added to model
New gene 26027.1 added to model
New gene 10058.1 added to model
New gene 51458.1 added to model
New gene 948.1 added to model
New gene 10928.1 added to model
New gene 1728.1 added to model
New gene 2946.1 added to model
New gene 125981.1 added to model
New gene 55331.1 added to model
New gene 340485.1 added to model
New gene 5660.1 added to model
New gene 2760.1 added to model
New gene 57704.1 added to model
New gene 4759.1 added to model
New gene 10825.1 added to model
New gene 7903.1 added to model
New gene 2170.1 added to model
New gene 2169.1 added to model
New gene 2173.1 added to model
New gene 2171.1 added to model
New gene 2172.1 added to model
New gene 2167.1 added to model
New gene 646486.1 added to model
New gene 646480.1 added to model
New gene 6296.1 added to model
New gene 348158.1 added to model
New gene 54988.1 added to model
New gene 123876.1 added to model
New gene 341392.1 added to model
New gene 344967.1 added to model
New gene 55830.1 added to model
New gene 55650.1 added to model
New gene 9488.1 added to model
New gene 55624.1 added to model
New gene 55757.1 added to model
New gene 168391.1 added to model
New gene 80235.1 added to model
New gene 83468.1 added to model
New gene 8702.1 added to model
New gene 140687.1 added to model
New gene 3703.1 added to model
New gene 56886.1 added to model
New gene 283358.1 added to model
New gene 93183.1 added to model
New gene 8473.1 added to model
New gene 8707.1 added to model
New gene 148789.1 added to model
New gene 56983.1 added to model
New gene 201595.1 added to model
```

```
New gene 124872.1 added to model
New gene 146664.1 added to model
New gene 8708.1 added to model
New gene 84750.1 added to model
New gene 2529.1 added to model
New gene 338707.1 added to model
New gene 145173.1 added to model
New gene 200810.1 added to model
New gene 2526.1 added to model
New gene 170384.1 added to model
New gene 360203.1 added to model
New gene 152586.1 added to model
New gene 644378.1 added to model
New gene 84752.1 added to model
New gene 644974.1 added to model
New gene 51228.1 added to model
New gene 284004.1 added to model
New gene 11102.1 added to model
New gene 91179.1 added to model
New gene 8644.1 added to model
New gene 4645.1 added to model
New gene 1646.1 added to model
New gene 8630.1 added to model
New gene 158160.1 added to model
New gene 51144.1 added to model
New gene 51170.1 added to model
New gene 3995.1 added to model
New gene 114571.1 added to model
New gene 123096.1 added to model
New gene 93650.1 added to model
New gene 92370.1 added to model
New gene 390928.1 added to model
New gene 139596.1 added to model
New gene 55066.1 added to model
New gene 8974.1 added to model
New gene 5033.1 added to model
New gene 283208.1 added to model
New gene 259307.1 added to model
New gene 51312.1 added to model
New gene 81894.1 added to model
New gene 220074.1 added to model
New gene 57171.1 added to model
New gene 7837.1 added to model
New gene 137902.1 added to model
New gene 158584.1 added to model
New gene 55244.1 added to model
New gene 146802.1 added to model
New gene 51171.1 added to model
New gene 10202.1 added to model
New gene 10553.1 added to model
New gene 84869.1 added to model
New gene 1487.1 added to model
New gene 56898.1 added to model
New gene 374875.1 added to model
New gene 121214.1 added to model
New gene 100288072.1 added to model
New gene 93517.1 added to model
New gene 51741.1 added to model
New gene 340811.1 added to model
New gene 57016.1 added to model
New gene 441282.1 added to model
```

```
New gene 133121.1 added to model
New gene 123264.1 added to model
New gene 200931.1 added to model
New gene 10941.1 added to model
New gene 79799.1 added to model
New gene 513.1 added to model
New gene 498.2 added to model
New gene 506.1 added to model
New gene 509.2 added to model
New gene 514.1 added to model
New gene 513.2 added to model
New gene 514.2 added to model
New gene 509.1 added to model
New gene 498.1 added to model
New gene 498.3 added to model
New gene 10632.1 added to model
New gene 4905.1 added to model
New gene 10476.1 added to model
New gene 9551.3 added to model
New gene 522.5 added to model
New gene 516.2 added to model
New gene 521.1 added to model
New gene 515.1 added to model
New gene 518.3 added to model
New gene 515.2 added to model
New gene 10476.2 added to model
New gene 522.3 added to model
New gene 517.2 added to model
New gene 9551.2 added to model
New gene 518.2 added to model
New gene 9551.1 added to model
New gene 522.4 added to model
New gene 522.2 added to model
New gene 515.3 added to model
New gene 522.1 added to model
New gene 517.1 added to model
New gene 516.1 added to model
New gene 518.1 added to model
New gene 539.1 added to model
New gene 267020.1 added to model
New gene 27109.1 added to model
New gene 7384.1 added to model
New gene 7388.1 added to model
New gene 4519.1 added to model
New gene 29796.2 added to model
New gene 10975.1 added to model
New gene 7385.1 added to model
New gene 7386.1 added to model
New gene 1537.1 added to model
New gene 27089.1 added to model
New gene 7381.1 added to model
New gene 29796.1 added to model
New gene 9016.1 added to model
New gene 7352.2 added to model
New gene 7352.1 added to model
New gene 7351.1 added to model
New gene 9016.2 added to model
New gene 9481.1 added to model
New gene 4715.1 added to model
New gene 4720.1 added to model
New gene 4719.1 added to model
New gene 4700.1 added to model
New gene 55967.1 added to model
New gene 4709.1 added to model
New gene 4710.1 added to model
```

```
New gene 4726.1 added to model
New gene 4718.1 added to model
New gene 4696.1 added to model
New gene 4694.1 added to model
New gene 374291.1 added to model
New gene 4728.1 added to model
New gene 4712.2 added to model
New gene 4717.1 added to model
New gene 4705.1 added to model
New gene 4725.1 added to model
New gene 4716.1 added to model
New gene 4537.1 added to model
New gene 7991.1 added to model
New gene 4722.1 added to model
New gene 4541.1 added to model
New gene 4539.1 added to model
New gene 4707.1 added to model
New gene 4701.1 added to model
New gene 4723.1 added to model
New gene 4698.1 added to model
New gene 4538.1 added to model
New gene 4697.1 added to model
New gene 51079.1 added to model
New gene 4714.1 added to model
New gene 4704.1 added to model
New gene 126328.1 added to model
New gene 4711.1 added to model
New gene 4724.1 added to model
New gene 4713.1 added to model
New gene 4536.1 added to model
New gene 4695.1 added to model
New gene 4702.1 added to model
New gene 4708.1 added to model
New gene 4535.1 added to model
New gene 4731.2 added to model
New gene 4706.1 added to model
New gene 4729.1 added to model
New gene 4540.1 added to model
New gene 7991.2 added to model
New gene 4731.1 added to model
New gene 4712.1 added to model
New gene 54539.1 added to model
```

```
New gene 1351.1 added to model
New gene 1347.1 added to model
New gene 1329.1 added to model
New gene 1327.1 added to model
New gene 341947.1 added to model
New gene 9167.1 added to model
New gene 1350.1 added to model
New gene 4512.1 added to model
New gene 1349.1 added to model
New gene 1339.1 added to model
New gene 1345.1 added to model
New gene 4513.1 added to model
New gene 9377.1 added to model
New gene 125965.1 added to model
New gene 4514.1 added to model
New gene 170712.1 added to model
New gene 1346.1 added to model
New gene 1340.1 added to model
New gene 84701.1 added to model
New gene 1337.1 added to model
```

Save the resulting model.

```
save('SubNetworkRecon.mat','modelConsistent')
```

Size of the original Recon:

```
[nMet,nRxn] = size(model.S);
fprintf('%6s\t%6s\n','#mets','#rxns'); fprintf('%6u\t%6u\t%s%s\n',nMet,nRxn,' total in Recon')
```

```
  #mets  #rxns
   5835  10600  total in Recon
```

Size of the resulting Recon subnetwork:

```
[nMet,nRxn] = size(modelConsistent.S);
fprintf('%6s\t%6s\n','#mets','#rxns'); fprintf('%6u\t%6u\t%s%s\n',nMet,nRxn,' total in Recon s
```

```
  #mets  #rxns
   3991   7721  total in Recon subnetwork
```

Consider to evaluate the resulting model with the tutorial modelProperties and modelSanityChecks to ensure proper functioning of the generic subnetwork of Recon.

References

[1] Brunk, E. et al. Recon 3D: A resource enabling a three-dimensional view of gene variation in human metabolism. (submitted) 2017.

[2] HMR 2.0

[3] Drug module.

[4] FastCore.


```

```