

# Package ‘httk’

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**Title** High-Throughput Toxicokinetics

**Description** Functions and data tables for simulation and statistical analysis of chemical toxicokinetics (“TK”) as in Pearce et al. (2017) <doi:10.18637/jss.v079.i04>. Chemical-specific in vitro data have been obtained from relatively high throughput experiments. Both physiologically-based (“PBTK”) and empirical (e.g., one compartment) “TK” models can be parameterized for several hundred chemicals and multiple species. These models are solved efficiently, often using compiled (C-based) code. A Monte Carlo sampler is included for simulating biological variability (Ring et al., 2017 <doi:10.1016/j.envint.2017.06.004>) and measurement limitations. Calibrated methods are included for predicting tissue:plasma partition coefficients and volume of distribution (Pearce et al., 2017 <doi:10.1007/s10928-017-9548-7>). These functions and data provide a set of tools for in vitro-in vivo extrapolation (“IVIVE”) of high throughput screening data (e.g., Tox21, ToxCast) to real-world exposures via reverse dosimetry (also known as “RTK”) (Wetmore et al., 2015 <doi:10.1093/toxsci/kfv171>).

**Depends** R (>= 2.10)

**Imports** deSolve, msm, data.table, survey, mvtnorm, truncnorm, stats, utils, magrittr

**Suggests** ggplot2, knitr, rmarkdown, R.rsp, GGally, gplots, scales, EnvStats, MASS, RColorBrewer, TeachingDemos, classInt, ks, reshape2, gdata, viridis, CensRegMod, gmodels, colorspace

**License** GPL-3

**LazyData** true

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**RoxygenNote** 6.1.1

**URL** <https://www.epa.gov/chemical-research/rapid-chemical-exposure-and-dose-research>

[//www.epa.gov/chemical-research/rapid-chemical-exposure-and-dose-research](https://www.epa.gov/chemical-research/rapid-chemical-exposure-and-dose-research)

**BugReports** <https://github.com/USEPA/CompTox-ExpoCast-httk>

**NeedsCompilation** yes

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**Repository** CRAN

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httk-package

*High-Throughput Toxicokinetics*


---

## Description

Functions and data tables for simulation and statistical analysis of chemical toxicokinetics ("TK") as in Pearce et al. (2017) <doi:10.18637/jss.v079.i04>. Chemical-specific in vitro data have been obtained from relatively high throughput experiments. Both physiologically-based ("PBTCK") and empirical (e.g., one compartment) "TK" models can be parameterized for several hundred chemicals and multiple species. These models are solved efficiently, often using compiled (C-based) code. A Monte Carlo sampler is included for simulating biological variability (Ring et al., 2017 <doi:10.1016/j.envint.2017.06.004>) and measurement limitations. Calibrated methods are included for predicting tissue:plasma partition coefficients and volume of distribution (Pearce et al., 2017 <doi:10.1007/s10928-017-9548-7>). These functions and data provide a set of tools for in vitro-in vivo extrapolation ("IVIVE") of high throughput screening data (e.g., Tox21, ToxCast) to real-world exposures via reverse dosimetry (also known as "RTK") (Wetmore et al., 2015 <doi:10.1093/toxsci/kfv171>).

**Author(s)**

John Wambaugh, Robert Pearce, Caroline Ring, Gregory Honda, Nisha Sipes, Jimena Davis, Barbara Wetmore, Woodrow Setzer

**See Also**

PowerPoint Presentation: High-Throughput Toxicokinetics (HTTK) R package

Pearce et al. (2017): [httk: R Package for High-Throughput Toxicokinetics](#)

Wetmore et al. (2015): [Incorporating High-Throughput Exposure Predictions With Dosimetry-Adjusted In Vitro Bioactivity to Inform Chemical Toxicity Testing](#)

Wambaugh et al. (2015): [Toxicokinetic Triage for Environmental Chemicals](#)

Pearce et al. (2017): [Evaluation and calibration of high-throughput predictions of chemical distribution to tissues](#)

Ring et al. (2017): [Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability](#)

Sipes et al. (2017): [An Intuitive Approach for Predicting Potential Human Health Risk with the Tox21 10k Library](#)

Wambaugh et al. (2018): [Evaluating In Vitro-In Vivo Extrapolation of Toxicokinetics](#)

[EPA's ExpoCast \(Exposure Forecasting\) Project](#)

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add_chemtable	<i>Add a table of chemical information for use in making httk predictions.</i>
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---

**Description**

This function adds chemical-specific information to the table `chem.physical_and_invitro.data`. This table is queried by the model parameterization functions when attempting to parameterize a model, so adding sufficient data to this table allows additional chemicals to be modeled.

**Usage**

```
add_chemtable(new.table, data.list, current.table=NULL,
              reference=NULL, species=NULL, overwrite=F)
```

**Arguments**

<code>new.table</code>	Object of class <code>data.frame</code> containing one row per chemical, with each chemical minimally by described by a CAS number.
<code>data.list</code>	This list identifies which properties are to be read from the table. Each item in the list should point to a column in the table <code>new.table</code> . Valid names in the list are: <code>'Compound'</code> , <code>'CAS'</code> , <code>'DSSTox.GSID'</code> , <code>'SMILES.desalt'</code> , <code>'Reference'</code> , <code>'Species'</code> , <code>'MW'</code> , <code>'logP'</code> , <code>'pKa_Donor'</code> , <code>'pKa_Accept'</code> , <code>'logMA'</code> , <code>'Clint'</code> , <code>'Clint.pValue'</code> , <code>'Funbound.plasma'</code> , <code>'Fgutabs'</code> , <code>'Rblood2plasma'</code> .
<code>current.table</code>	This is the table to which data are being added.

reference	This is the reference for the data in the new table. This may be omitted if a column in data.list gives the reference value for each chemical.
species	This is the species for the data in the new table. This may be omitted if a column in data.list gives the species value for each chemical or if the data are not species-specific (e.g., MW).
overwrite	If overwrite=TRUE then data in current.table will be replaced by any data in new.table that is for the same chemical and property. If overwrite=FALSE (DEFAULT) then new data for the same chemical and property are ignored. Funbound.plasma values of 0 (below limit of detection) are overwritten either way.

**Value**

data.frame	A new data.frame containing the data in current.table augmented by new.table
------------	--

**Author(s)**

John Wambaugh

**Examples**

```
my.new.data <- as.data.frame(c("A", "B", "C"), stringsAsFactors=FALSE)
my.new.data <- cbind(my.new.data, as.data.frame(c("111-11-2", "222-22-0", "333-33-5"),
  stringsAsFactors=FALSE))
my.new.data <- cbind(my.new.data, as.data.frame(c(200, 200, 200)))
my.new.data <- cbind(my.new.data, as.data.frame(c(2, 3, 4)))
my.new.data <- cbind(my.new.data, as.data.frame(c(0.01, 0.02, 0.3)))
my.new.data <- cbind(my.new.data, as.data.frame(c(0, 10, 100)))
colnames(my.new.data) <- c("Name", "CASRN", "MW", "LogP", "Fup", "CLint")

chem.physical_and_invitro.data <- add_chemtable(my.new.data,
  current.table=chem.physical_and_invitro.data,
  data.list=list(
    Compound="Name",
    CAS="CASRN",
    MW="MW",
    logP="LogP",
    Funbound.plasma="Fup",
    Clint="CLint"),
  species="Human",
  reference="MyPaper 2015")

parameterize_steadystate(chem.name="C")
calc_css(chem.name="B")
```

---

age\_dist\_smooth

*Smoothed age distributions by race and gender.*

---

**Description**

Distributions of ages in months, computed from NHANES data smoothed using survey::svsmooth(), for each combination of race/ethnicity and gender.

**Usage**

```
age_dist_smooth
```

**Format**

A data.table object with three variables:

gender Gender: Male or Female

reth Race/ethnicity

smth A list of svsmooth objects, each encoding a weighted smoothed distribution of ages.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

age_draw_smooth	<i>Draws ages from a smoothed distribution for a given gender/race combination</i>
-----------------	--

---

**Description**

Draws ages from a smoothed distribution for a given gender/race combination

**Usage**

```
age_draw_smooth(g, r, nsamp, agelim_months)
```

**Arguments**

g	Gender. Either 'Male' or 'Female'.
r	Race/ethnicity. One of 'Mexican American', 'Other Hispanic', 'Non-Hispanic Black', 'Non-Hispanic White', 'Other'.
nsamp	Number of ages to draw.
agelim_months	Two-element numeric vector giving the minimum and maximum ages in months to include.

**Value**

A named list with members 'ages\_months' and 'ages\_years', each numeric of length nsamp, giving the sampled ages in months and years.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

armitage\_estimate\_sarea

*Estimate well surface area*

---

**Description**

Estimate geometry surface area of plastic in well plate based on well plate format suggested values from Corning. option.plastic == T (default) give nonzero surface area (sarea, m<sup>2</sup>) option.bottom == T (default) includes surface area of the bottom of the well in determining sarea. Optionally include user values for working volume (v\_working, m<sup>3</sup>) and surface area.

**Usage**

```
armitage_estimate_sarea(tcdata = NA, this.well_number = 384,
  this.cell_yield = NA, this.v_working = NA)
```

**Arguments**

tcdata	A data table with well_number corresponding to plate format, optionally include v_working, sarea, option.bottom, and option.plastic
this.well_number	For single value, plate format default is 384, used if is.na(tcdata)==T
this.cell_yield	For single value, optionally supply cell_yield, otherwise estimated based on well number
this.v_working	For single value, optionally supply working volume, otherwise estimated based on well number (m <sup>3</sup> )

**Value**

tcdata, A data table with well\_number, sarea (surface area, m<sup>2</sup>), cell\_yield (# cells), v\_working (m<sup>3</sup>), v\_total (m<sup>3</sup>) per well

**Author(s)**

Greg Honda



armitage\_eval

*Evaluate the updated Armitage model***Description**

Evaluate the Armitage model for chemical distribution in vitro. Takes input as data table or single set of values. Outputs a data table. Updates over the model published in Armitage et al. 2014 include binding to plastic walls and lipid and protein compartments in cells.

**Usage**

```
armitage_eval(tcdata = NA, this.casrn, this.ac50 = 10, this.MP = NA,
  this.gkow = NA, this.gkaw = NA, this.gswat = NA, this.sarea = NA,
  this.v_total = NA, this.v_working = NA, this.cell_yield = NA,
  this.Tsys = 37, this.Tref = 298.15, this.option.kbsa2 = F,
  this.option.swat2 = F, this.FBSf = 0, this.pseudooct = 0.01,
  this.memblip = 0.04, this.nlom = 0.2, this.P_nlom = 0.035,
  this.P_dom = 0.05, this.P_cells = 1, this.csalt = 0.15,
  this.celldensity = 1, this.cellmass = 3, this.f_oc = 1)
```

**Arguments**

tcdata	A data.table with casrn, ac50, MP, gkow, gkaw, gswat, sarea, v_total, v_working. Otherwise supply single values to this.params.
this.casrn	For single value, CAS number
this.ac50	For single value, AC50 (micromolar) nominal concentration
this.MP	For single value, melting point (oC)
this.gkow	For single value, Log10 Kow, octanol-water partitioning coefficient
this.gkaw	For single value, Log10 Kaw, air-water partitioning coefficient
this.gswat	For single value, Log10 water solubility (mol/L)
this.sarea	For single value, surface area per well (m^2)
this.v_total	For single value, Total volume per well (m^3)
this.v_working	For single value, Working volume per well (m^3)
this.cell_yield	For single value, Number of cells per well
this.Tsys	System temperature (oC)
this.Tref	Reference temperature (K)
this.option.kbsa2	Use alternative bovine-serum-albumin partitioning model
this.option.swat2	Use alternative water solubility correction
this.FBSf	Fraction fetal bovine serum

<code>this.pseudooct</code>	Pseudo-octanol cell storage lipid content
<code>this.memblip</code>	Membrane lipid content of cells
<code>this.nlom</code>	Structural protein content of cells
<code>this.P_nlom</code>	Proportionality constant to octanol structural protein
<code>this.P_dom</code>	Proportionality constant to octanol dom
<code>this.P_cells</code>	Proportionality constant to octanol storage lipid
<code>this.csalt</code>	Ionic strength of buffer, mol/L
<code>this.celldensity</code>	Cell density kg/L, g/mL
<code>this.cellmass</code>	Mass per cell, ng/cell
<code>this.f_oc</code>	1, everything assumed to be like proteins

**Value**

tcddata

**Author(s)**

Greg Honda

**References**

Armitage, J. M.; Wania, F.; Arnot, J. A. *Environ. Sci. Technol.* 2014, 48, 9770-9779. [dx.doi.org/10.1021/es501955g](https://doi.org/10.1021/es501955g)  
 Honda et al. (submitted) "Using the Concordance of In Vitro and In Vivo Data to Evaluate Extrapolation Assumptions"

---

armitage\_input

*Armitage et al. (2014) Model Inputs from Honda et al. (submitted)*

---

**Description**

Armitage et al. (2014) Model Inputs from Honda et al. (submitted)

**Usage**

armitage\_input

**Format**

A data frame with 53940 rows and 10 variables:

**MP**  
**MW**  
**casrn**  
**compound\_name**  
**gkaw**  
**gkow**  
**gswat**

**Author(s)**

Greg Honda

**Source**

<http://www.diamondse.info/>

**References**

Armitage, J. M.; Wania, F.; Arnot, J. A. Environ. Sci. Technol. 2014, 48, 9770-9779. dx.doi.org/10.1021/es501955g

Honda, Gregory S., et al. "Using the Concordance of In Vitro and In Vivo Data to Evaluate Extrapolation Assumptions", submitted.

---

available\_rblood2plasma

*Find the best available ratio of the blood to plasma concentration constant.*

---

**Description**

This function finds the best available constant ratio of the blood concentration to the plasma concentration, using `get_rblood2plasma` and `calc_rblood2plasma`.

**Usage**

```
available_rblood2plasma(chem.cas=NULL, chem.name=NULL, species="Human",  
                        adjusted.Funbound.plasma=T)
```

**Arguments**

<code>chem.name</code>	Either the chemical name or the CAS number must be specified.
<code>chem.cas</code>	Either the CAS number or the chemical name must be specified.
<code>species</code>	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
<code>adjusted.Funbound.plasma</code>	Whether or not to use Funbound.plasma adjustment if calculating Rblood2plasma.

## Details

If available, in vivo data (from chem.physical\_and\_invitro.data) for the given species is returned, substituting the human in vivo value when missing for other species. In the absence of in vivo data, the value is calculated with calc\_rblood2plasma for the given species. If Funbound.plasma is unavailable for the given species, the human Funbound.plasma is substituted. If none of these are available, the mean human Rblood2plasma from chem.physical\_and\_invitro.data is returned.

## Author(s)

Robert Pearce

## Examples

```
available_rblood2plasma(chem.name="Bisphenol A",adjusted.Funbound.plasma=FALSE)
available_rblood2plasma(chem.name="Bisphenol A",species="Rat")
```

---

blood\_mass\_correct      *Find average blood masses by age.*

---

## Description

If blood mass from [blood\\_weight](#) is negative or very small, then just default to the mean blood mass by age. (Geigy Scientific Tables, 7th ed.)

## Usage

```
blood_mass_correct(blood_mass, age_months, age_years, gender, weight)
```

## Arguments

blood_mass	A vector of blood masses in kg to be replaced with averages.
age_months	A vector of ages in months.
age_years	A vector of ages in years.
gender	A vector of genders (either 'Male' or 'Female').
weight	A vector of body weights in kg.

## Value

A vector of blood masses in kg.

---

blood_weight	<i>Predict blood mass.</i>
--------------	----------------------------

---

**Description**

Predict blood mass based on body surface area and gender, using equations from Bosgra et al. 2012

**Usage**

```
blood_weight(BSA, gender)
```

**Arguments**

BSA	Body surface area in m <sup>2</sup> . May be a vector.
gender	Either 'Male' or 'Female'. May be a vector.

**Value**

A vector of blood masses in kg the same length as BSA and gender.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

bmiage	<i>CDC BMI-for-age charts</i>
--------	-------------------------------

---

**Description**

Charts giving the BMI-for-age percentiles for boys and girls ages 2-18

**Usage**

```
bmiage
```

**Format**

A data.table object with variables

Sex 'Male' or 'Female'

Agemos Age in months

L, M, S LMS parameters; see [www.cdc.gov/growthcharts/percentile\\_data\\_files.htm](http://www.cdc.gov/growthcharts/percentile_data_files.htm)

P3, P5, P10, P25, P50, P75, P85, P90, P95, and P97 BMI percentiles

**Details**

For children ages 2 to 18, weight class depends on the BMI-for-age percentile.

**Underweight** <5th percentile

**Normal weight** 5th-85th percentile

**Overweight** 85th-95th percentile

**Obese** >=95th percentile

**Author(s)**

Caroline Ring

**Source**

[www.cdc.gov/growthcharts/percentile\\_data\\_files.htm](http://www.cdc.gov/growthcharts/percentile_data_files.htm)

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

body\_surface\_area      *Predict body surface area.*

---

**Description**

Predict body surface area from weight, height, and age, using Mosteller's formula for age>18 and Haycock's formula for age<18

**Usage**

body\_surface\_area(BW, H, age\_years)

**Arguments**

BW                      A vector of body weights in kg.

H                        A vector of heights in cm.

age\_years            A vector of ages in years.

**Value**

A vector of body surface areas in cm<sup>2</sup>.

---

bone_mass_age	<i>Predict bone mass.</i>
---------------	---------------------------

---

**Description**

Predict bone mass from age\_years, height, weight, gender, using logistic equations fit to data from Baxter-Jones et al. 2011, or for infants < 1 year, using equation from Koo et al. 2000 (See Price et al. 2003)

**Usage**

```
bone_mass_age(age_years, age_months, height, weight, gender)
```

**Arguments**

age_years	Vector of ages in years.
age_months	Vector of ages in months.
height	Vector of heights in cm.
weight	Vector of body weights in kg.
gender	Vector of genders, either 'Male' or 'Female'.

**Value**

Vector of bone masses.

---

brain_mass	<i>Predict brain mass.</i>
------------	----------------------------

---

**Description**

Predict brain mass from gender and age.

**Usage**

```
brain_mass(gender, age_years)
```

**Arguments**

gender	Vector of genders, either 'Male' or 'Female'
age_years	Vector of ages in years.

**Value**

A vector of brain masses in kg.

---

calc\_analytic\_css      *Calculate the analytic steady state concentration.*

---

### Description

This function calculates the analytic steady state plasma or venous blood concentrations as a result of infusion dosing for the three compartment and multiple compartment PBTK models.

### Usage

```
calc_analytic_css(chem.name = NULL, chem.cas = NULL,
  parameters = NULL, daily.dose = 1, output.units = "uM",
  model = "pbtk", species = "Human", concentration = "plasma",
  suppress.messages = F, recalc.blood2plasma = F,
  default.to.human = F, tissue = NULL, well.stirred.correction = T,
  adjusted.funbound.plasma = T, regression = T,
  restrictive.clearance = T, IVIVE = NULL, ...)
```

### Arguments

chem.name	Either the chemical name, CAS number, or the parameters must be specified.
chem.cas	Either the chemical name, CAS number, or the parameters must be specified.
parameters	Chemical parameters from parameterize_pbtk (for model = 'pbtk'), parameterize_3comp (for model = '3compartment'), parameterize_1comp (for model = '1compartment') or parameterize_steadystate (for model = '3compartmentss'), overrides chem.name and chem.cas.
daily.dose	Total daily dose, mg/kg BW.
output.units	Units for returned concentrations, defaults to uM (specify units = "uM") but can also be mg/L.
model	Model used in calculation, 'pbtk' for the multiple compartment model, '3compartment' for the three compartment model, '3compartmentss' for the three compartment steady state model, and '1compartment' for one compartment model.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
concentration	Desired concentration type, 'blood' or default 'plasma'.
suppress.messages	Whether or not the output message is suppressed.
recalc.blood2plasma	Recalculates the ratio of the amount of chemical in the blood to plasma using the input parameters, calculated with hematocrit, Funbound.plasma, and Krbc2pu.
default.to.human	Substitutes missing rat values with human values if true.
tissue	Desired tissue concentration, overwrites concentration argument.



well.stirred.correction	Uses correction in calculation of hepatic clearance for well-stirred model if TRUE for model 1compartment and 3compartmentss. This assumes clearance relative to amount unbound in whole blood instead of plasma, but converted to use with plasma concentration.
adjusted.funbound.plasma	Uses adjusted Funbound.plasma when set to TRUE along with partition coefficients calculated with this value.
restrictive.clearance	If TRUE (default), then only the fraction of chemical not bound to protein is available for metabolism in the liver. If FALSE, then all chemical in the liver is metabolized (faster metabolism due to rapid off-binding).
IVIVE	Honda et al. (submitted) identified six plausible sets of assumptions for <i>in vitro-in vivo</i> extrapolation (IVIVE) assumptions. Argument may be set to "Honda1" through "Honda6". If used, this function overwrites the tissue, restrictive.clearance, and plasma.binding arguments. See Details below for more information.
...	Additional parameters passed to parameterize functions if parameters is NULL.
regression	Whether or not to use the regressions in calculating partition coefficients.

## Details

Tissue concentrations are calculated for the pbtk model with oral infusion dosing. All tissues other than gut, liver, and lung are the product of the steady state plasma concentration and the tissue to plasma partition coefficient.

	<i>in vivo</i> Conc.	Metabolic Clearance	Bioactive Chemical Conc.	TK Statistic Used*
Honda1	Veinous (Plasma)	Restrictive	Free	Mean Conc.
Honda2	Veinous	Restrictive	Free	Max Conc.
Honda3	Veinous	Non-restrictive	Total	Mean Conc.
Honda4	Veinous	Non-restrictive	Total	Max Conc.
Honda5	Target Tissue	Non-restrictive	Total	Mean Conc.
Honda6	Target Tissue	Non-restrictive	Total	Max Conc.

\*Assumption is currently ignored because analytical steady-state solutions are currently used by this function.

## Value

Steady state concentration

## Author(s)

Robert Pearce and John Wambaugh

## References

Honda, Gregory S., et al. "Using the Concordance of In Vitro and In Vivo Data to Evaluate Extrapolation Assumptions", submitted.

## Examples

```
calc_analytic_css(chem.name='Bisphenol-A',output.units='mg/L',
                 model='3compartment',concentration='blood')
calc_analytic_css(chem.name='Bisphenol-A',tissue='liver',species='rabbit',
                 default.to.human=TRUE,daily.dose=2)
calc_analytic_css(chem.name="bisphenol a",model="1compartment")
calc_analytic_css(chem.cas="80-05-7",model="3compartmentss")
params <- parameterize_pbt(chem.cas="80-05-7")
calc_analytic_css(parameters=params,model="pbt")
```

---

calc\_css

*Find the steady state concentration and the day it is reached.*

---

## Description

This function finds the day a chemical comes within the specified range of the analytical steady state venous blood or plasma concentration(from calc\_analytic\_css) for the multiple compartment, three compartment, and one compartment models, the fraction of the true steady state value reached on that day, the maximum concentration, and the average concentration at the end of the simulation.

## Usage

```
calc_css(parameters=NULL,chem.name=NULL,chem.cas=NULL,species="Human", f = .01,
         daily.dose=1, doses.per.day=3,days = 21,output.units = "uM",
         concentration='plasma',suppress.messages=F,model='pbt',default.to.human=F,
         f.change=0.00001,adjusted.funbound.plasma=T,regression=T,
         well.stirred.correction=T, restrictive.clearance=T,...)
```

## Arguments

chem.name	Either the chemical name, CAS number, or parameters must be specified.
chem.cas	Either the chemical name, CAS number, or parameters must be specified.
f	Fractional distance from the final steady state concentration that the average concentration must come within to be considered at steady state.
parameters	Chemical parameters from parameterize_pbt function, overrides chem.name and chem.cas.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
daily.dose	Total daily dose, mg/kg BW.
doses.per.day	Number of doses per day.

days	Initial number of days to run simulation that is multiplied on each iteration.
output.units	Units for returned concentrations, defaults to uM (specify units = "uM") but can also be mg/L.
concentration	Desired concentration type, 'blood' or default 'plasma'.
suppress.messages	Whether or not to suppress messages.
model	Model used in calculation, 'pbtk' for the multiple compartment model, '3compartment' for the three compartment model, and '1compartment' for the one compartment model.
default.to.human	Substitutes missing animal values with human values if true (hepatic intrinsic clearance or fraction of unbound plasma).
f.change	Fractional change of daily steady state concentration reached to stop calculating.
adjusted.funbound.plasma	Uses adjusted Funbound.plasma when set to TRUE along with partition coefficients calculated with this value.
regression	Whether or not to use the regressions in calculating partition coefficients.
well.stirred.correction	Uses correction in calculation of hepatic clearance for well-stirred model if TRUE for model 1compartment elimination rate. This assumes clearance relative to amount unbound in whole blood instead of plasma, but converted to use with plasma concentration.
restrictive.clearance	Protein binding not taken into account (set to 1) in liver clearance if FALSE.
...	Additional arguments passed to model solver (default of solve_pbtk).

### Value

frac	Ratio of the mean concentration on the day steady state is reached (based on doses.per.day) to the analytical C <sub>ss</sub> (based on infusion dosing).
max	The maximum concentration of the simulation.
avg	The average concentration on the final day of the simulation.
the.day	The day the average concentration comes within 100 * p percent of the true steady state concentration.

### Author(s)

Robert Pearce

### Examples

```
calc_css(chem.name='Bisphenol-A', doses.per.day=5, f=.001, output.units='mg/L')
## Not run:
parms <- parameterize_3comp(chem.name='Bisphenol-A')
parms$Funbound.plasma <- .07
calc_css(parms, concentration='blood', model='3compartment')
```

```

library("ggplot2")
out <- solve_pbtck(chem.name = "Bisphenol A", days = 50, doses.per.day = 3)
plot.data <- as.data.frame(out)
css <- calc_analytic_css(chem.name = "Bisphenol A")
c.vs.t <- ggplot(plot.data, aes(time, Cplasma)) + geom_line() +
  geom_hline(yintercept = css) + ylab("Plasma Concentration (uM)") +
  xlab("Day") + theme(axis.text = element_text(size = 16), axis.title =
  element_text(size = 16), plot.title = element_text(size = 17)) +
  ggtitle("Bisphenol A")
print(c.vs.t)

days <- NULL
avg <- NULL
max <- NULL
for(this.cas in get_cheminfo()){
  css.info <- calc_css(chem.cas = this.cas, doses.per.day = 1, suppress.messages=T)
  days[[this.cas]] <- css.info[["the.day"]]
  avg[[this.cas]] <- css.info[["avg"]]
  max[[this.cas]] <- css.info[["max"]]
}
days.data <- as.data.frame(days)
hist <- ggplot(days.data, aes(days)) +
  geom_histogram(fill = "blue", binwidth = 1/6) + scale_x_log10() +
  ylab("Number of Chemicals") + xlab("Days") + theme(axis.text =
  element_text(size = 16), axis.title = element_text(size = 16))
print(hist)
avg.max.data <- as.data.frame(cbind(avg, max))
avg.vs.max <- ggplot(avg.max.data, aes(avg, max)) + geom_point() +
  geom_abline() + scale_x_log10() + scale_y_log10() +
  xlab("Average Concentration at Steady State (uM)") +
  ylab("Max Concentration at Steady State (uM)") +
  theme(axis.text = element_text(size = 16),
  axis.title = element_text(size = 16))
print(avg.vs.max)

## End(Not run)

```

---

calc\_elimination\_rate *Calculate the elimination rate for a one compartment model.*

---

### Description

This function calculates an elimination rate from the three compartment steady state model where elimination is entirely due to metabolism by the liver and glomerular filtration in the kidneys.

### Usage

```
calc_elimination_rate(chem.cas=NULL, chem.name=NULL, parameters=NULL,
```

```
species="Human", suppress.messages=F, default.to.human=F,  
restrictive.clearance=T, adjusted.funbound.plasma=T,  
regression=T, well.stirred.correction=T,  
clint.pvalue.threshold = 0.05)
```

### Arguments

chem.name	Either the chemical name or the cas number must be specified.
chem.cas	Either the cas number or the chemical name must be specified.
parameters	Chemical parameters from parameterize_steadystate or 1compartment function, overrides chem.name and chem.cas.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
suppress.messages	Whether or not the output message is suppressed.
default.to.human	Substitutes missing animal values with human values if true.
adjusted.funbound.plasma	Uses adjusted funbound.plasma when set to TRUE along with partition coefficients calculated with this value.
regression	Whether or not to use the regressions in calculating partition coefficients.
restrictive.clearance	In calculating elimination rate, protein binding is not taken into account (set to 1) in liver clearance if FALSE.
well.stirred.correction	Uses correction in calculation of hepatic clearance for well-stirred model if TRUE. This assumes clearance relative to amount unbound in whole blood instead of plasma, but converted to use with plasma concentration.
clint.pvalue.threshold	Hepatic clearance for chemicals where the in vitro clearance assay result has a p-values greater than the threshold are set to zero.

### Details

Elimination rate calculated by dividing the total clearance (using the default well-stirred hepatic model) by the volume of distribution.

### Value

Elimination rate  
Units of 1/h.

### Author(s)

John Wambaugh

**Examples**

```

calc_elimination_rate(chem.name="Bisphenol A")
calc_elimination_rate(chem.name="Bisphenol A",species="Rat")
calc_elimination_rate(chem.cas="80-05-7")

```

---

calc\_hepatic\_clearance

*Calculate the hepatic clearance.*

---

**Description**

This function calculates the hepatic clearance in plasma for a well-stirred model or other type if specified.

**Usage**

```

calc_hepatic_clearance(chem.name=NULL,chem.cas=NULL,parameters=NULL,
                      species='Human',default.to.human=F,
                      hepatic.model='well-stirred',
                      suppress.messages=F,well.stirred.correction=T,
                      restrictive.clearance=T,adjusted.funbound.plasma=T,...)

```

**Arguments**

chem.name	Either the chemical name, CAS number, or the parameters must be specified.
chem.cas	Either the chemical name, CAS number, or the parameters must be specified.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
default.to.human	Substitutes missing animal values with human values if true.
parameters	Chemical parameters from parameterize_steadystate function, overrides chem.name and chem.cas.
hepatic.model	Model used in calculating hepatic clearance, unscaled, parallel tube, dispersion, or default well-stirred.
suppress.messages	Whether or not to suppress the output message.
well.stirred.correction	Uses correction in calculation of hepatic clearance for well-stirred model if TRUE for hepatic.model well-stirred. This assumes clearance relative to amount unbound in whole blood instead of plasma, but converted to use with plasma concentration.
restrictive.clearance	Protein binding not taken into account (set to 1) in liver clearance if FALSE.
adjusted.funbound.plasma	Uses adjusted Funbound.plasma when set to TRUE.
...	Additional parameters passed to parameterize_steadystate if parameters is NULL.

**Value**

Hepatic Clearance  
Units of L/h/kg BW.

**Author(s)**

John Wambaugh

**Examples**

```
calc_hepatic_clearance(chem.name="Ibuprofen",hepatic.model='unscaled')  
calc_hepatic_clearance(chem.name="Ibuprofen",well.stirred.correction=FALSE)
```

---

calc\_ionization      *Calculate the ionization.*

---

**Description**

This function calculates the ionization of a compound at a given pH. The pKa's are either entered as parameters or taken from a specific compound in the package.

**Usage**

```
calc_ionization(chem.cas=NULL,  
               chem.name=NULL,  
               parameters=NULL,  
               pH=NULL,  
               pKa_Donor=NA,  
               pKa_Accept=NA)
```

**Arguments**

chem.name	Either the chemical name or the CAS number must be specified.
chem.cas	Either the chemical name or the CAS number must be specified.
parameters	Chemical parameters from a parameterize_MODEL function, overrides chem.name and chem.cas.
pH	pH where ionization is evaluated.
pKa_Donor	Compound H dissociation equilibrium constant(s). Overwrites chem.name and chem.cas.
pKa_Accept	Compound H association equilibrium constant(s). Overwrites chem.name and chem.cas.

**Details**

The fractions are calculated by determining the coefficients for each species and dividing the particular species by the sum of all three. The positive, negative and zwitterionic/neutral coefficients are given by:

$$\text{zwitter/neutral} = 1$$

$$\text{for}(iin1 : pkabove)\text{negative} = \text{negative} + 10^{(i * pH - pKa1 - \dots - pKai)}$$

$$\text{for}(iin1 : pkbelow)\text{positive} = \text{positive} + 10^{(pKa1 + \dots + pKai - i * pH)}$$

where i begins at 1 and ends at the number of points above(for negative) or below(for positive) the neutral/zwitterionic range. The neutral/zwitterionic range is either the pH range between 2 pKa's where the number of acceptors above is equal to the number of donors below, everything above the pKa acceptors if there are no donors, or everything below the pKa donors if there are no acceptors. Each of the terms in the sums represent a different ionization.

**Value**

fraction\_neutral  
fraction of compound neutral

fraction\_charged  
fraction of compound charged

fraction\_negative  
fraction of compound negative

fraction\_positive  
fraction of compound positive

fraction\_zwitter  
fraction of compound zwitterionic

**Author(s)**

Robert Pearce

**References**

Pearce, Robert G., et al. "Evaluation and calibration of high-throughput predictions of chemical distribution to tissues." *Journal of pharmacokinetics and pharmacodynamics* 44.6 (2017): 549-565.

**Examples**

```
calc_ionization(chem.name='bisphenola',pH=7.4)
calc_ionization(pKa_Donor=8,pKa_Accept=c(1,4),pH=9)
```



---

 calc\_mc\_css

*Find the monte carlo steady state concentration.*


---

### Description

This function finds the analytical steady state plasma concentration(from calc\_analytic\_css) using a monte carlo simulation (monte\_carlo).

### Usage

```
calc_mc_css(chem.cas = NULL, chem.name = NULL, parameters = NULL,
            daily.dose = 1, which.quantile = 0.95, species = "Human",
            output.units = "mg/L", suppress.messages = F,
            model = "3compartmentss",
            censored.params = list(Funbound.plasma = list(cv = 0.3, lod = 0.01)),
            vary.params = list(BW = 0.3, Vliverc = 0.3, Qgfr = 0.3,
                               Qtotal.liverc = 0.3,
                               million.cells.per.gliver = 0.3, Clint = 0.3),
            samples = 1000, return.samples = F, default.to.human = F,
            tissue = NULL, well.stirred.correction = T,
            adjusted.Funbound.plasma = T, regression = T,
            clint.pvalue.threshold = 0.05,
            restrictive.clearance = T,
            tk.statistic.used = "mean",
            IVIVE=NULL,
            httkpop = T,
            poormetab = T, fup.censor = T,
            Clint.vary = T, sigma.factor = 0.3, lod = 0.01,
            method = "direct resampling", gendernum = NULL,
            agelim_years = NULL, agelim_months = NULL,
            weight_category = c("Underweight", "Normal", "Overweight", "Obese"),
            gfr_category = c("Normal", "Kidney Disease", "Kidney Failure"),
            reths = c("Mexican American", "Other Hispanic",
                     "Non-Hispanic White", "Non-Hispanic Black", "Other"),
            physiology.matrix = NULL, parameter.matrix = NULL,
            ...)
```

### Arguments

chem.name	Either the chemical parameters, name, or the CAS number must be specified.
chem.cas	Either the CAS number, parameters, or the chemical name must be specified.
parameters	Parameters from parameterize_steadystate. Not used with httkpop model.
daily.dose	Total daily dose, mg/kg BW/day.
which.quantile	Which quantile from Monte Carlo simulation is requested. Can be a vector.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human"). Species must be set to "Human" to run httkpop model.

output.units	Plasma concentration units, either uM or default mg/L.
suppress.messages	Whether or not to suppress output message.
censored.params	The parameters listed in censored.params are sampled from a normal distribution that is censored for values less than the limit of detection (specified separately for each parameter). This argument should be a list of sub-lists. Each sublist is named for a parameter in "parameters" and contains two elements: "CV" (coefficient of variation) and "LOD" (limit of detection, below which parameter values are censored. New values are sampled with mean equal to the value in "parameters" and standard deviation equal to the mean times the CV. Censored values are sampled on a uniform distribution between 0 and the limit of detection. Not used with httkpop model.
vary.params	The parameters listed in vary.params are sampled from a normal distribution that is truncated at zero. This argument should be a list of coefficients of variation (CV) for the normal distribution. Each entry in the list is named for a parameter in "parameters". New values are sampled with mean equal to the value in "parameters" and standard deviation equal to the mean times the CV. Not used with httkpop model.
samples	Number of samples generated in calculating quantiles.
return.samples	Whether or not to return the vector containing the samples from the simulation instead of the selected quantile.
default.to.human	Substitutes missing rat values with human values if true.
tissue	Desired steady state tissue concentration.
adjusted.funbound.plasma	Uses adjusted Funbound.plasma when set to TRUE along with partition coefficients calculated with this value.
regression	Whether or not to use the regressions in calculating partition coefficients.
well.stirred.correction	If TRUE (default) then the well-stirred correction (Rowland et al., 1973) is used in the calculation of hepatic clearance for the models that do not include flows for first-pass metabolism (currently, 1compartment and 3compartmentss). This assumes clearance relative to amount unbound in whole blood instead of plasma, but converted for use with plasma concentration.
restrictive.clearance	Protein binding not taken into account (set to 1) in liver clearance if FALSE.
tk.statistic.used	Theoretically either the "mean" or "maximum" (peak) concentrations might be used for IVIVE with some models. Defaults to "mean". Meaningless for the steady-state model (Argument is currently ignored because analytic steady-state solutions are used by this function.).
IVIVE	Honda et al. (submitted) identified six plausible sets of assumptions for <i>in vitro-in vivo</i> extrapolation (IVIVE) assumptions. Argument may be set to "Honda1" through "Honda6". If used, this function overwrites the tissue, restrictive.clearance, and plasma.binding arguments. See Details below for more information.

httkpop	Whether or not to use population generator and sampler from httkpop. This is overwrites censored.params and vary.params and is only for human physiology. Species must also be set to 'Human'.
model	Model used in calculation: 'pbtk' for the multiple compartment model, '3compartment' for the three compartment model, '3compartments' for the three compartment steady state model, and '1compartment' for one compartment model. This only applies when httkpop=TRUE and species="Human", otherwise '3compartments' is used.
poormetab	TRUE (include poor metabolizers) or FALSE (exclude poor metabolizers)
fup.censor	TRUE (draw Funbound.plasma from a censored distribution) or FALSE (draw Funbound.plasma from a non-censored distribution)
sigma.factor	The coefficient of variation to use for Clint and Funbound.plasma distributions. Default value is 0.3.
Clint.vary	TRUE (sample Clint values) or FALSE (hold Clint fixed). Default TRUE. If Clint.vary is FALSE, then poormetab will have no effect.
lod	The average limit of detection for Funbound.plasma. if fup.censor == TRUE, the Funbound.plasma distribution will be censored below lod/2. Default value is 0.01.
method	The population-generation method to use. Either "virtual individuals" or "direct resampling" (default). Short names may be used: "d" or "dr" for "direct resampling", and "v" or "vi" for "virtual individuals".
gendernum	Optional: A named list giving the numbers of male and female individuals to include in the population, e.g. list(Male=100,Female=100). Default is NULL, meaning both males and females are included, in their proportions in the NHANES data. If both nsamp and gendernum are provided, they must agree (i.e., nsamp must be the sum of gendernum).
agelim_years	Optional: A two-element numeric vector giving the minimum and maximum ages (in years) to include in the population. Default is c(0,79). If only a single value is provided, both minimum and maximum ages will be set to that value; e.g. agelim_years=3 is equivalent to agelim_years=c(3,3). If agelim_years is provided and agelim_months is not, agelim_years will override the default value of agelim_months.
agelim_months	Optional: A two-element numeric vector giving the minimum and maximum ages (in months) to include in the population. Default is c(0,959), equivalent to the default agelim_years. If only a single value is provided, both minimum and maximum ages will be set to that value; e.g. agelim_months=36 is equivalent to agelim_months=c(36,36). If agelim_months is provided and agelim_years is not, agelim_months will override the default values of agelim_years.
weight_category	Optional: The weight categories to include in the population. Default is c('Underweight', 'Normal', 'Overweight'). User-supplied vector must contain one or more of these strings.
gfr_category	The kidney function categories to include in the population. Default is c('Normal', 'Kidney Disease', 'End Stage Renal Disease'), to include all kidney function levels.
reth	Optional: a character vector giving the races/ethnicities to include in the population. Default is c('Mexican American', 'Other Hispanic', 'Non-Hispanic White', 'Non-Hispanic Black', 'Hispanic', 'Other').

to include all races and ethnicities in their proportions in the NHANES data. User-supplied vector must contain one or more of these strings.

`physiology.matrix`  
A data table generated by `httkpop_generate()`.

`parameter.matrix`  
A data table generated by `get_httk_params()`.

`clint.pvalue.threshold`  
Hepatic clearance for chemicals where the *in vitro* clearance assay result has a p-values greater than the threshold are set to zero.

`...`  
Additional parameters passed to `calc_analytic_css`

## Details

All arguments after `httkpop` only apply if `httkpop` is set to `TRUE` and `species` to "Human".

When `species` is specified as `rabbit`, `dog`, or `mouse`, the function uses the appropriate physiological data (volumes and flows) but substitutes human fraction unbound, partition coefficients, and intrinsic hepatic clearance.

Tissue concentrations are calculated for the `pbtk` model with oral infusion dosing. All tissues other than gut, liver, and lung are the product of the steady state plasma concentration and the tissue to plasma partition coefficient.

The six sets of plausible *in vitro-in vivo* extrapolation (IVIVE) assumptions identified by Honda et al. (submitted) are:

	<i>in vivo</i> Conc.	Metabolic Clearance	Bioactive Chemical Conc.	TK Statistic Used*
Honda1	Veinous (Plasma)	Restrictive	Free	Mean Conc.
Honda2	Veinous	Restrictive	Free	Max Conc.
Honda3	Veinous	Non-restrictive	Total	Mean Conc.
Honda4	Veinous	Non-restrictive	Total	Max Conc.
Honda5	Target Tissue	Non-restrictive	Total	Mean Conc.
Honda6	Target Tissue	Non-restrictive	Total	Max Conc.

\*Assumption is currently ignored because analytical steady-state solutions are currently used by this function.

## Author(s)

original by John Wambaugh, rewritten by Caroline Ring and Robert Pearce

## References

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment international* 106 (2017): 105-118. Honda, Gregory S., et al. "Using the Concordance of In Vitro and In Vivo Data to Evaluate Extrapolation Assumptions", submitted. Rowland, Malcolm, Leslie Z. Benet, and Garry G. Graham. "Clearance concepts in pharmacokinetics." *Journal of pharmacokinetics and biopharmaceutics* 1.2 (1973): 123-136.



**Arguments**

conc	Bioactive in vitro concentration in units of uM.
chem.name	Either the chemical name or the CAS number must be specified.
chem.cas	Either the CAS number or the chemical name must be specified.
suppress.messages	Suppress text messages.
input.units	Units of given concentration, default of uM but can also be mg/L.
output.units	Units of dose, default of 'mg' for mg/kg BW/ day or 'mol' for mol/ kg BW/ day.
which.quantile	Which quantile from Monte Carlo steady-state simulation (calc_mc_css) is requested. Can be a vector. Note that 95th concentration quantile is the same population as the 5th dose quantile.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
return.samples	Whether or not to return the vector containing the samples from the simulation instead of the selected quantile.
restrictive.clearance	Protein binding not taken into account (set to 1) in liver clearance if FALSE.
plasma.binding	If TRUE, then only the free (unbound) fraction of chemical is considered to be bioactive. If FALSE, the total chemical concentration is used for IVIVE. (Default TRUE)
tk.statistic.used	Theoretically either the "mean" or "maximum" (peak) concentrations might be used for IVIVE with some models. Defaults to "mean". Meaningless for the steady-state model (Argument is currently ignored because analytic steady-state solutions are used by this function.).
tissue	Desired steady state tissue concentration.
IVIVE	Honda et al. (submitted) identified six plausible sets of assumptions for <i>in vitro-in vivo</i> extrapolation (IVIVE) assumptions. Argument may be set to "Honda1" through "Honda6". If used, this function overwrites the tissue, restrictive.clearance, and plasma.binding arguments. See Details below for more information.
...	Additional parameters passed to calc_mc_css for httkpop and variance of parameters.

**Details**

All arguments after httkpop only apply if httkpop is set to TRUE and species to "Human".

When species is specified as rabbit, dog, or mouse, the function uses the appropriate physiological data(volumes and flows) but substitutes human fraction unbound, partition coefficients, and intrinsic hepatic clearance.

Tissue concentrations are calculated for the pbtk model with oral infusion dosing. All tissues other than gut, liver, and lung are the product of the steady state plasma concentration and the tissue to plasma partition coefficient.

The six sets of plausible *in vitro-in vivo* extrapolation (IVIVE) assumptions identified by Honda et al. (submitted) are:

	<i>in vivo</i> Conc.	Metabolic Clearance	Bioactive Chemical Conc.	TK Statistic Used*
Honda1	Veinous (Plasma)	Restrictive	Free	Mean Conc.
Honda2	Veinous	Restrictive	Free	Max Conc.
Honda3	Veinous	Non-restrictive	Total	Mean Conc.
Honda4	Veinous	Non-restrictive	Total	Max Conc.
Honda5	Target Tissue	Non-restrictive	Total	Mean Conc.
Honda6	Target Tissue	Non-restrictive	Total	Max Conc.

\*Assumption is currently ignored because analytical steady-state solutions are currently used by this function.

### Value

Equivalent dose in specified units, default of mg/kg BW/day.

### Author(s)

John Wambaugh

### Examples

```
## Not run:
calc_mc_oral_equiv(0.1, chem.cas="34256-82-1", which.quantile=c(0.05, 0.5, 0.95),
  method='vi', samples=100, tissue='brain')

## End(Not run)
```

---

calc\_rblood2plasma      *Calculate the constant ratio of the blood concentration to the plasma concentration.*

---

### Description

This function calculates the constant ratio of the blood concentration to the plasma concentration.

### Usage

```
calc_rblood2plasma(chem.cas=NULL, chem.name=NULL, params = NULL,
  hematocrit = NULL, default.to.human=F,
  species="Human", adjusted.funbound.plasma=T)
```

**Arguments**

chem.name	Either the chemical name or the CAS number must be specified.
chem.cas	Either the CAS number or the chemical name must be specified.
params	Parameters from parameterize_schmitt.
hematocrit	Overwrites default hematocrit value in calculating Rblood2plasma.
default.to.human	Substitutes missing animal values with human values if true.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
adjusted.funbound.plasma	Whether or not to use Funbound.plasma adjustment.

**Details**

The red blood cell (RBC) partition coefficient as predicted by the Schmitt (2008) method is used in the calculation. The value is calculated with the equation:  $1 - \text{hematocrit} + \text{hematocrit} * K_{\text{rbc2pu}} * \text{Funbound.plasma}$ , summing the red blood cell to plasma and plasma:plasma (equal to 1) partition coefficients multiplied by their respective fractional volumes.

**Author(s)**

John Wambaugh

**References**

Schmitt W. "General approach for the calculation of tissue to plasma partition coefficients." Toxicology In Vitro, 22, 457-467 (2008).

**Examples**

```
calc_rblood2plasma(chem.name="Bisphenol A")
calc_rblood2plasma(chem.name="Bisphenol A",species="Rat")
```

---

calc\_stats

*Calculate the statistics.*

---

**Description**

This function calculates the area under the curve, the mean, and the peak values for the venous blood or plasma concentration of a specified chemical or all chemicals if none is specified for the multiple compartment model with a given number of days, dose, and number of doses per day.

**Usage**

```
calc_stats(days,chem.name=NULL,chem.cas=NULL,parameters=NULL,stats=c("AUC","peak","mean"),
           species='Human',exclude.fub.zero=F,daily.dose=1,dose=NULL,doses.per.day=NULL,
           output.units='uM',concentration='plasma',model='pbtk',
           default.to.human=F,suppress.messages=F,...)
```



**Arguments**

days	Length of the simulation.
chem.name	Name of desired chemical.
chem.cas	CAS number of desired chemical.
parameters	Chemical parameters from parameterize_pbt function, overrides chem.name and chem.cas.
stats	Desired values (either 'AUC', 'mean', 'peak', or a vector containing any combination).
daily.dose	Total daily dose, mg/kg BW.
dose	Amount of a single dose, mg/kg BW. Overwrites daily.dose.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
exclude.fub.zero	Whether or not to exclude chemicals with a fraction of unbound plasma equal to zero or include them with a value of 0.005, only used when chem.name, chem.cas, and parameters are not specified.
doses.per.day	Number of doses per day.
output.units	Desired units (either "mg/L", "mg", "umol", or default "uM").
model	Model used in calculation, 'pbt' for the multiple compartment model, '3compartment' for the three compartment model, '3compartmentss' for the three compartment steady state model, and '1compartment' for one compartment model.
concentration	Desired concentration type, 'blood' or default 'plasma'.
default.to.human	Substitutes missing animal values with human values if true (hepatic intrinsic clearance or fraction of unbound plasma).
suppress.messages	Whether to suppress output message.
...	Arguments passed to solve function.

**Details**

Default value of 0 for doses.per.day solves for a single dose.

**Value**

AUC	Area under the plasma concentration curve.
mean	The area under the curve divided by the number of days.
peak	The highest concentration.

**Author(s)**

John Wambaugh and Robert Pearce

**Examples**

```

calc_stats(chem.name='Bisphenol-A', days=100, stats='mean', model='3compartment')
calc_stats(chem.name='Bisphenol-A', days=100, stats=c('peak', 'mean'), species='Rat')
## Not run:
all.peak.stats <- calc_stats(days=10, doses.per.day = 3, stats = "peak")

## End(Not run)
triclosan.stats <- calc_stats(days=10, chem.name = "triclosan")

```

---

calc\_total\_clearance *Calculate the total clearance.*

---

**Description**

This function calculates the total clearance rate for a one compartment model where clearance is entirely due to metabolism by the liver and glomerular filtration in the kidneys, identical to clearance of three compartment steady state model.

**Usage**

```

calc_total_clearance(chem.cas=NULL, chem.name=NULL, parameters=NULL, species="Human",
                    suppress.messages=F, default.to.human=F, well.stirred.correction=T,
                    restrictive.clearance=T, adjusted.funbound.plasma=T, ...)

```

**Arguments**

chem.name	Either the chemical name, CAS number, or the parameters must be specified.
chem.cas	Either the chemical name, CAS number, or the parameters must be specified.
parameters	Chemical parameters from parameterize_steadystate function, overrides chem.name and chem.cas.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
suppress.messages	Whether or not the output message is suppressed.
default.to.human	Substitutes missing animal values with human values if true.
adjusted.funbound.plasma	Uses adjusted Funbound.plasma when set to TRUE.
restrictive.clearance	Protein binding is not taken into account (set to 1) in liver clearance if FALSE.
well.stirred.correction	Uses correction in calculation of hepatic clearance for well-stirred model if TRUE. This assumes clearance relative to amount unbound in whole blood instead of plasma, but converted to use with plasma concentration.
...	Additional parameters passed to parameterize_steadystate if parameters is NULL.

**Value**

Total Clearance  
Units of L/h/kg BW.

**Author(s)**

John Wambaugh

**Examples**

```
calc_total_clearance(chem.name="Ibuprofen")
```

---

calc\_vdist

*Calculate the volume of distribution for a one compartment model.*

---

**Description**

This function predicts partition coefficients for all tissues, then lumps them into a single compartment.

**Usage**

```
calc_vdist(chem.cas=NULL, chem.name=NULL, parameters=NULL,
           default.to.human=F, species="Human", suppress.messages=F,
           adjusted.funbound.plasma=T, regression=T)
```

**Arguments**

chem.name	Either the chemical name or the CAS number must be specified when Funbound.plasma is not given in parameter list.
chem.cas	Either the CAS number or the chemical name must be specified when Funbound.plasma is not given in parameter list.
parameters	Parameters from parameterize_3comp, parameterize_pbtk or predict_partitioning_schmitt.
default.to.human	Substitutes missing animal values with human values if true.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
suppress.messages	Whether or not the output message is suppressed.
adjusted.funbound.plasma	Uses adjusted Funbound.plasma when set to TRUE along with partition coefficients calculated with this value.
regression	Whether or not to use the regressions in calculating partition coefficients.

**Details**

The effective volume of distribution is calculated by summing each tissues volume times it's partition coefficient relative to plasma. Plasma, and the partitioning into RBCs are also added to get the total volume of distribution in L/KG BW. Partition coefficients are calculated using Schmitt's (2008) method.

**Value**

Volume of distribution  
Units of L/ kg BW.

**Author(s)**

John Wambaugh

**References**

Schmitt W. "General approach for the calculation of tissue to plasma partition coefficients." *Toxicology In Vitro*, 22, 457-467 (2008). Peyret, T., Poulin, P., Krishnan, K., "A unified algorithm for predicting partition coefficients for PBPK modeling of drugs and environmental chemicals." *Toxicology and Applied Pharmacology*, 249, 197-207 (2010).

**Examples**

```
calc_vdist(chem.cas="80-05-7")  
calc_vdist(chem.name="Bisphenol A")  
calc_vdist(chem.name="Bisphenol A",species="Rat")
```

---

chem.invivo.PK.aggregate.data

*Parameter Estimates from Wambaugh et al. (2018)*

---

**Description**

This table includes 1 and 2 compartment fits of plasma concentration vs time data aggregated from chem.invivo.PK.data, performed in Wambaugh et al. 2018. Data includes volume of distribution (Vdist, L/kg), elimination rate (kelim, 1/h), gut absorption rate (kgutabs, 1/h), fraction absorbed (Fgutabs), and steady state concentration (Css, mg/L).

**Usage**

chem.invivo.PK.aggregate.data

**Format**

data.frame

**Author(s)**

John Wambaugh

**Source**

Wambaugh et al. 2018 Toxicological Sciences, in press

---

chem.invivo.PK.data *Published toxicokinetic time course measurements*

---

**Description**

This data set includes time and dose specific measurements of chemical concentration in tissues taken from animals administered control doses of the chemicals either orally or intravenously. This plasma concentration-time data is from rat experiments reported in public sources. Toxicokinetic data were retrieved from those studies by the Netherlands Organisation for Applied Scientific Research (TNO) using curve stripping (TechDig v2). This data is provided for statistical analysis as in Wambaugh et al. 2018.

**Usage**

chem.invivo.PK.data

**Format**

A data.frame containing 597 rows and 13 columns.

**Author(s)**

Sieto Bosgra

**Source**

Wambaugh et al. 2018 Toxicological Sciences, in press

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---

chem.invivo.PK.summary.data

*Summary of published toxicokinetic time course experiments*

---

## Description

This data set summarizes the time course data in the chem.invivo.PK.data table. Maximum concentration (Cmax), time integrated plasma concentration for the duration of treatment (AUC.treatment) and extrapolated to zero concentration (AUC.infinity) as well as half-life are calculated. Summary values are given for each study and dosage. These data can be used to evaluate toxicokinetic model predictions.

## Usage

chem.invivo.PK.summary.data

## Format

A data.frame containing 100 rows and 25 columns.

## Author(s)

John Wambaugh

## Source

Wambaugh et al. 2018 *Toxicological Sciences*, in press



## References

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---

chem.lists

*Chemical membership in different research projects*

---

### **Description**

A static list of lists identifying chemical membership in different research projects. While it is our intent to keep these lists up-to-date, the information here is only for convenience and should not be considered to be definitive.

### **Usage**

chem.lists

### **Format**

A list containing ten lists.

**Author(s)**

John Wambaugh

**References**

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---

chem.physical\_and\_invitro.data

*Physico-chemical properties and in vitro measurements for toxicokinetics*

---

**Description**

This data set contains the necessary information to make basic, high-throughput toxicokinetic (HTTK) predictions for compounds, including Funbound.plasma, molecular weight (g/mol), logP, logMA (membrane affinity), intrinsic clearance(uL/min/10<sup>6</sup> cells), and pKa. These data have been compiled from multiple sources, and can be used to parameterize a variety of toxicokinetic models.

**Usage**

chem.physical\_and\_invitro.data

**Format**

A data.frame containing 565 rows and 33 columns.

**Author(s)**

John Wambaugh

**Source**

Wambaugh, John F., et al. "Toxicokinetic triage for environmental chemicals." Toxicological Sciences (2015): 228-237.

## References

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---

 ckd\_epi\_eq

*CKD-EPI equation for GFR.*


---

### Description

Predict GFR from serum creatinine, gender, race, and age.

### Usage

```
ckd_epi_eq(scr, gender, reth, age_years)
```

### Arguments

scr	Vector of serum creatinine values in mg/dL.
gender	Vector of genders (either 'Male' or 'Female').
reth	Vector of races/ethnicities.
age_years	Vector of ages in years.

### Details

From Levey AS, Stevens LA, Schmid CH, Zhang YL, Castro AF, Feldman HI, et al. A new equation to estimate glomerular filtration rate. *Ann Intern Med* 2009; 150(9):604-612. doi:10.7326/0003-4819-150-9-200905050-00006

### Value

Vector of GFR values in mL/min/1.73m<sup>2</sup>.

### Author(s)

Caroline Ring

## References

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

convert_httk	<i>Converts HHTK-Pop virtual population into parameters relevant to an HHTK model.</i>
--------------	--

---

## Description

Converts HHTK-Pop virtual population into parameters relevant to an HHTK model.

## Usage

```
convert_httk(indiv.model.bio, model, this.chem = NULL,
             parameters = NULL, adjusted.funbound.plasma = T, regression = T,
             well.stirred.correction = T, restrictive.clearance = T,
             clint.pvalue.threshold = 0.05)
```

## Arguments

indiv.model.bio	A data.table containing the physiological parameters as expected by HHTK (from <a href="#">httkpop.bio</a> ) and Funbound.plasma and Clint values (from <a href="#">draw_fup_clint</a> ).
model	Which HHTK model to use. One of '1compartment', '3compartments', '3compartment', or 'pbtk'.
this.chem	CAS number for the chemical in the HHTK data set (see <a href="#">get_cheminfo</a> ) for which parameters are to be generated.
parameters	A list of chemical-specific model parameters containing at least Funbound.plasma, Clint, and Fhеп.assay.correction.
adjusted.funbound.plasma	Uses adjusted Funbound.plasma when set to TRUE.
regression	Whether or not to use the regressions in calculating partition coefficients.
well.stirred.correction	Uses correction in calculation of hepatic clearance for well-stirred model if TRUE for hepatic.model well-stirred. This assumes clearance relative to amount unbound in whole blood instead of plasma, but converted to use with plasma concentration.
restrictive.clearance	Protein binding not taken into account (set to 1) in liver clearance if FALSE.
clint.pvalue.threshold	Hepatic clearance for chemicals where the in vitro clearance assay result has a p-values greater than the threshold are set to zero.

## Value

A data.table whose columns are the parameters of the HHTK model specified in model.

---

draw_fup_clint	<i>Draw Funbound.plasma and Clint from censored or non-censored distributions.</i>
----------------	--

---

### Description

Given a CAS in the HHTK data set, a virtual population from HHTK-Pop, some user specifications on the assumed distributions of Funbound.plasma and Clint, draw "individual" values of Funbound.plasma and Clint from those distributions.

### Usage

```
draw_fup_clint(this.chem = NULL, parameters = NULL, nsamp,
  sigma.factor = 0.3, poormetab, fup.censor, Clint.vary = TRUE,
  lod = 0.01, adjusted.Funbound.plasma = T,
  clint.pvalue.threshold = 0.05)
```

### Arguments

this.chem	The CAS number of one of the HHTK chemicals (see <a href="#">get_cheminfo</a> ).
parameters	A list of chemical-specific model parameters containing at least Funbound.plasma, Clint, and Fhеп.assay.correction.
nsamp	The number of samples to draw.
sigma.factor	The coefficient of variance to assume. Default 0.3.
poormetab	Logical. Whether to include poor metabolizers in the Clint distribution or not.
fup.censor	Logical. Whether to draw Funbound.plasma from a censored distribution or not.
Clint.vary	Logical, default TRUE. Whether to treat Clint as fixed at its measured value (FALSE), or as a random variable (TRUE).
lod	The average limit of detection for Funbound.plasma, below which distribution will be censored if fup.censor is TRUE. Default 0.01.
adjusted.Funbound.plasma	Uses adjusted Funbound.plasma when set to TRUE.
clint.pvalue.threshold	Hepatic clearance for chemicals where the in vitro clearance assay result has a p-values greater than the threshold are set to zero.

### Value

A data.table with three columns: Funbound.plasma and Clint, containing the sampled values, and Fhеп.assay.correction, containing the value for fraction unbound in hepatocyte assay.

### Author(s)

Caroline Ring and John Wambaugh



---

estimate_gfr	<i>Predict GFR.</i>
--------------	---------------------

---

**Description**

First predict serum creatinine using smoothing spline, then predict GFR using CKD-EPI equation.

**Usage**

```
estimate_gfr(gfrtmp.dt)
```

**Arguments**

gfrtmp.dt	A data.table with columns gender, reth, age_years, age_months, BSA_adj, serum_creat.
-----------	--

**Value**

The same data.table with a gfr\_est column added, containing estimated GFR values.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

estimate_gfr_ped	<i>Predict GFR in children.</i>
------------------	---------------------------------

---

**Description**

BSA-based equation from Johnson et al. 2006, *Clin Pharmacokinet* 45(9) 931-56. Used in Wetmore et al. 2014.

**Usage**

```
estimate_gfr_ped(BSA)
```

**Arguments**

BSA	Vector of body surface areas in m <sup>2</sup> .
-----	--

**Value**

Vector of GFRs in mL/min/1.73m<sup>2</sup>.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

estimate\_hematocrit *Predict hematocrit using smoothing spline.*

---

**Description**

Using precalculated smoothing splines on NHANES log hematocrit vs. age in months (and KDE residuals) by gender and race/ethnicity, generate hematocrit values for individuals specified by age, gender, and race/ethnicity.

**Usage**

```
estimate_hematocrit(hcttmp_dt)
```

**Arguments**

hcttmp\_dt      A data.table with columns age\_years, age\_months, gender, reth.

**Value**

The same data.table with a hematocrit column added.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

export\_pbtj\_jarnac      *Export model to jarnac.*

---

### Description

This function exports the multiple compartment PBTk model to a jarnac file.

### Usage

```
export_pbtj_jarnac(chem.cas=NULL, chem.name=NULL, species="Human",  
                  initial.amounts=list(Agutlumen=0), filename="default.jan", digits = 4)
```

### Arguments

chem.cas	Either the chemical name or CAS number must be specified.
chem.name	Either the chemical name or CAS number must be specified.
species	Species desired (either "Rat", "Rabbit", "Dog", or default "Human").
initial.amounts	Must specify initial amounts in units of choice.
filename	The name of the jarnac file containing the model.
digits	Desired number of decimal places to round the parameters.

### Details

Compartments to enter into the initial.amounts list includes Agutlumen, Aart, Aven, Alung, Agut, Aliver, Akidney, and Arest.

### Author(s)

Robert Pearce

### Examples

```
export_pbtj_jarnac(chem.name='Nicotine', initial.amounts=list(Agutlumen=1), filename='PBTkmodel.jan')
```

---

export_pbt_k_sbml	<i>Export model to sbml.</i>
-------------------	------------------------------

---

### Description

This function exports the multiple compartment PBTk model to an sbml file.

### Usage

```
export_pbt_k_sbml(chem.cas=NULL,chem.name=NULL,species="Human",  
                 initial.amounts=list(Agutlumen=0),filename="default.xml",digits = 4)
```

### Arguments

chem.cas	Either the chemical name or CAS number must be specified.
chem.name	Either the chemical name or CAS number must be specified.
species	Species desired (either "Rat", "Rabbit", "Dog", or default "Human").
initial.amounts	Must specify initial amounts in units of choice.
filename	The name of the jarnac file containing the model.
digits	Desired number of decimal places to round the parameters.

### Details

Compartments to enter into the initial.amounts list includes Agutlumen, Aart, Aven, Alung, Agut, Aliver, Akidney, and Arest.

### Author(s)

Robert Pearce

### Examples

```
export_pbt_k_sbml(chem.name='Nicotine',initial.amounts=list(Agutlumen=1),filename='PBTkmodel.xml')
```

---

gen\_age\_height\_weight *Generate ages, heights, and weights for a virtual population using the virtual-individuals method.*

---

### Description

Generate ages, heights, and weights for a virtual population using the virtual-individuals method.

### Usage

```
gen_age_height_weight(nsamp = NULL, gendernum = NULL, reths,
  weight_category, agelim_years, agelim_months)
```

### Arguments

nsamp	The desired number of individuals in the virtual population. nsamp need not be provided if gendernum is provided.
gendernum	Optional: A named list giving the numbers of male and female individuals to include in the population, e.g. <code>list(Male=100,Female=100)</code> . Default is NULL, meaning both males and females are included, in their proportions in the NHANES data. If both nsamp and gendernum are provided, they must agree (i.e., nsamp must be the sum of gendernum).
reths	Optional: a character vector giving the races/ethnicities to include in the population. Default is <code>c('Mexican American', 'Other Hispanic', 'Non-Hispanic White', 'Non-Hispanic Black')</code> . If NULL, all races and ethnicities in their proportions in the NHANES data. User-supplied vector must contain one or more of these strings.
weight_category	Optional: The weight categories to include in the population. Default is <code>c('Underweight', 'Normal', 'Overweight')</code> . User-supplied vector must contain one or more of these strings.
agelim_years	Optional: A two-element numeric vector giving the minimum and maximum ages (in years) to include in the population. Default is <code>c(0,79)</code> . If agelim_years is provided and agelim_months is not, agelim_years will override the default value of agelim_months.
agelim_months	Optional: A two-element numeric vector giving the minimum and maximum ages (in months) to include in the population. Default is <code>c(0, 959)</code> , equivalent to the default agelim_years. If agelim_months is provided and agelim_years is not, agelim_months will override the default values of agelim_years.

### Value

A data.table containing variables

gender Gender of each virtual individual

reth Race/ethnicity of each virtual individual

age\_months Age in months of each virtual individual

age\_years Age in years of each virtual individual  
 weight Body weight in kg of each virtual individual  
 height Height in cm of each virtual individual

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

gen_height_weight	<i>Generate heights and weights for a virtual population.</i>
-------------------	---

---

**Description**

Generate heights and weights for a virtual population.

**Usage**

```
gen_height_weight(hbw_dt)
```

**Arguments**

hbw\_dt A data.table describing the virtual population by race, gender, and age (in years and months). Must have variables gender, reth, age, and age.years.

**Value**

The same data.table with two new variables added: weight and height. Respectively, these give individual body weights in kg, and individual heights in cm.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

<code>get_cheminfo</code>	<i>Retrieve chemical information from HTKK package</i>
---------------------------	--

---

### Description

This function provides the information specified in "info=" (can be single entry or vector) for all chemicals for which a toxicokinetic model can be parameterized for a given species.

### Usage

```
get_cheminfo(info="CAS", species="Human", exclude.fub.zero=NA, fub.lod.default=0.005,
             model='3compartmentss', default.to.human=F)
```

### Arguments

<code>info</code>	A single character vector (or collection of character vectors) from "Compound", "CAS", "logP", "pKa_Donor", "pKa_Accept", "MW", "Clint", "Clint.pValue", "Funbound.plasma", "DSSTox_Substance_Id", "Structure_Formula", or "Substance_Type". <code>info="all"</code> gives all information for the model and species.
<code>species</code>	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
<code>exclude.fub.zero</code>	Whether or not to exclude chemicals with a fraction of unbound plasma equal to zero or include them with a value of <code>fub.lod.default</code> . Defaults to FALSE for '3compartmentss' and TRUE for pk models and schmitt.
<code>fub.lod.default</code>	Default value used for fraction of unbound plasma for chemicals where measured value was below the limit of detection. Default value is 0.0005.
<code>model</code>	Model used in calculation, 'pbtck' for the multiple compartment model, '1compartment' for the one compartment model, '3compartment' for three compartment model, '3compartmentss' for the three compartment model without partition coefficients, or 'schmitt' for chemicals with logP and fraction unbound (used in <code>predict_partitioning_schmitt</code> ).
<code>default.to.human</code>	Substitutes missing values with human values if true.

### Details

When `default.to.human` is set to TRUE, and the species-specific data, `Funbound.plasma` and `Clint`, are missing from `chem.physical_and_invitro.data`, human values are given instead.

### Value

<code>info</code>	Table/vector containing values specified in "info" for valid chemicals.
-------------------	---

### Author(s)

John Wambaugh

**Examples**

```
## Not run:
# List all CAS numbers for which the 3compartmentss model can be run in humans:
get_cheminfo()

get_cheminfo(info=c('compound','funbound.plasma','logP'),model='pbtk')
# See all the data for humans:
get_cheminfo(info="all")

TPO.cas <- c("741-58-2", "333-41-5", "51707-55-2", "30560-19-1", "5598-13-0",
"35575-96-3", "142459-58-3", "1634-78-2", "161326-34-7", "133-07-3", "533-74-4",
"101-05-3", "330-54-1", "6153-64-6", "15299-99-7", "87-90-1", "42509-80-8",
"10265-92-6", "122-14-5", "12427-38-2", "83-79-4", "55-38-9", "2310-17-0",
"5234-68-4", "330-55-2", "3337-71-1", "6923-22-4", "23564-05-8", "101-02-0",
"140-56-7", "120-71-8", "120-12-7", "123-31-9", "91-53-2", "131807-57-3",
"68157-60-8", "5598-15-2", "115-32-2", "298-00-0", "60-51-5", "23031-36-9",
"137-26-8", "96-45-7", "16672-87-0", "709-98-8", "149877-41-8", "145701-21-9",
"7786-34-7", "54593-83-8", "23422-53-9", "56-38-2", "41198-08-7", "50-65-7",
"28434-00-6", "56-72-4", "62-73-7", "6317-18-6", "96182-53-5", "87-86-5",
"101-54-2", "121-69-7", "532-27-4", "91-59-8", "105-67-9", "90-04-0",
"134-20-3", "599-64-4", "148-24-3", "2416-94-6", "121-79-9", "527-60-6",
"99-97-8", "131-55-5", "105-87-3", "136-77-6", "1401-55-4", "1948-33-0",
"121-00-6", "92-84-2", "140-66-9", "99-71-8", "150-13-0", "80-46-6", "120-95-6",
"128-39-2", "2687-25-4", "732-11-6", "5392-40-5", "80-05-7", "135158-54-2",
"29232-93-7", "6734-80-1", "98-54-4", "97-53-0", "96-76-4", "118-71-8",
"2451-62-9", "150-68-5", "732-26-3", "99-59-2", "59-30-3", "3811-73-2",
"101-61-1", "4180-23-8", "101-80-4", "86-50-0", "2687-96-9", "108-46-3",
"95-54-5", "101-77-9", "95-80-7", "420-04-2", "60-54-8", "375-95-1", "120-80-9",
"149-30-4", "135-19-3", "88-58-4", "84-16-2", "6381-77-7", "1478-61-1",
"96-70-8", "128-04-1", "25956-17-6", "92-52-4", "1987-50-4", "563-12-2",
"298-02-2", "79902-63-9", "27955-94-8")
httk.TPO.rat.table <- subset(get_cheminfo(info="all",species="rat"),
  CAS %in% TPO.cas)

httk.TPO.human.table <- subset(get_cheminfo(info="all",species="human"),
  CAS %in% TPO.cas)

## End(Not run)
```

---

```
get_gfr_category
```

```
Categorize kidney function by GFR.
```

---

**Description**

For adults: In general GFR > 60 is considered normal 15 < GFR < 60 is considered kidney disease  
GFR < 15 is considered kidney failure

**Usage**

```
get_gfr_category(age_years, age_months, gfr_est)
```



**Arguments**

age_years	Vector of ages in years.
age_months	Vector of ages in months.
gfr_est	Vector of estimated GFR values in mL/min/1.73m <sup>2</sup> .

**Details**

These values can also be used for children 2 years old and greater (see PEDIATRICS IN REVIEW Vol. 29 No. 10 October 1, 2008 pp. 335-341 (doi: 10.1542/pir.29-10-335))

**Value**

Vector of GFR categories: 'Normal', 'Kidney Disease', 'Kidney Failure'.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

get_httk_params	<i>Converts the HHTK-Pop population data table to a table of the parameters needed by HHTK, for a specific chemical.</i>
-----------------	--

---

**Description**

Takes the data table generated by `httkpop_generate`, and converts it to the corresponding table of HHTK model parameters for a specified chemical and HHTK model.

**Usage**

```
get_httk_params(indiv_dt, chemcas = NULL, parameters = NULL, model,
  poormetab, fup.censor, sigma.factor = 0.3, Clint.vary = TRUE,
  lod = 0.01, adjusted.Funbound.plasma = T, regression = T,
  well.stirred.correction = T, restrictive.clearance = T,
  clint.pvalue.threshold = 0.05)
```

**Arguments**

<code>indiv_dt</code>	A data table generated by <code>httkpop_generate()</code> .
<code>chemcas</code>	The CAS number of one of the HTTK chemicals (see <a href="#">get_cheminfo</a> ).
<code>parameters</code>	A list of chemical-specific model parameters containing at least <code>Funbound.plasma</code> , <code>Clint</code> , and <code>Fhep.assay.correction</code> .
<code>model</code>	One of the HTTK models: "1compartment", "3compartments", "3compartment", or "pbtk".
<code>poormetab</code>	TRUE (include poor metabolizers) or FALSE (exclude poor metabolizers)
<code>fup.censor</code>	TRUE (draw <code>Funbound.plasma</code> from a censored distribution) or FALSE (draw <code>Funbound.plasma</code> from a non-censored distribution)
<code>sigma.factor</code>	The coefficient of variation to use for <code>Clint</code> and <code>Funbound.plasma</code> distributions. Default value is 0.3.
<code>Clint.vary</code>	TRUE (sample <code>Clint</code> values) or FALSE (hold <code>Clint</code> fixed). Default TRUE. If <code>Clint.vary</code> is FALSE, then <code>poormetab</code> will have no effect.
<code>lod</code>	The average limit of detection for <code>Funbound.plasma</code> . if <code>fup.censor == TRUE</code> , the <code>Funbound.plasma</code> distribution will be censored below <code>lod/2</code> . Default value is 0.01.
<code>adjusted.Funbound.plasma</code>	Uses adjusted <code>Funbound.plasma</code> when set to TRUE.
<code>regression</code>	Whether or not to use the regressions in calculating partition coefficients. @examples <code>set.seed(42) indiv_examp &lt;- httkpop_generate(method="d", nsamp=100)</code> <code>httk_param &lt;- get_httk_params(indiv_dt=indiv_examp, chemcas="80-05-7", model="1compartment", poormetab=TRUE, fup.censor=TRUE)</code>
<code>well.stirred.correction</code>	If TRUE (default) then the well-stirred correction (Rowland et al., 1973) is used in the calculation of hepatic clearance for the models that do not include flows for first-pass metabolism (currently, 1compartment and 3compartments). This assumes clearance relative to amount unbound in whole blood instead of plasma, but converted for use with plasma concentration.
<code>restrictive.clearance</code>	Protein binding not taken into account (set to 1) in liver clearance if FALSE.
<code>clint.pvalue.threshold</code>	Hepatic clearance for chemicals where the in vitro clearance assay result has a p-values greater than the threshold are set to zero.

**Value**

A data.table whose columns correspond to the parameters of the HTTK model specified in `model`, and whose rows correspond to the individuals (rows) of `indiv_dt`. #' @param `well.stirred.correction` Uses correction in calculation of hepatic clearance for well-stirred model if TRUE for hepatic.model well-stirred. This assumes clearance relative to amount unbound in whole blood instead of plasma, but converted to use with plasma concentration.

**Author(s)**

Caroline Ring and John Wambaugh

## References

- Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118
- Rowland, Malcolm, Leslie Z. Benet, and Garry G. Graham. "Clearance concepts in pharmacokinetics." *Journal of Pharmacokinetics and Biopharmaceutics* 1.2 (1973): 123-136.

---

get\_lit\_cheminfo      *Get literature Chemical Information.*

---

## Description

This function provides the information specified in "info=" for all chemicals with data from the Wetmore et al. (2012) and (2013) publications and other literature.

## Usage

```
get_lit_cheminfo(info="CAS", species="Human")
```

## Arguments

info	A single character vector (or collection of character vectors) from "Compound", "CAS", "MW", "Raw.Expe", "r2", "p.val", "Concentration.uM.", "Css_lower_5th_perc.mg.L.", "Css_median_perc.mg.L.", "Css_upper_5th_perc.mg.L." and "Species".
species	Species desired (either "Rat" or default "Human").

## Value

info	Table/vector containing values specified in "info" for valid chemicals.
------	---

## Author(s)

John Wambaugh

## References

- Wetmore, B.A., Wambaugh, J.F., Ferguson, S.S., Sochaski, M.A., Rotroff, D.M., Freeman, K., Clewell, H.J., Dix, D.H., Andersen, M.E., Houck, K.A., Allen, B., Judson, R.S., Sing, R., Kavlock, R.J., Richard, A.M., and Thomas, R.S., "Integration of Dosimetry, Exposure and High-Throughput Screening Data in Chemical Toxicity Assessment," *Toxicological Sciences* 125 157-174 (2012)
- Wetmore, B.A., Wambaugh, J.F., Ferguson, S.S., Li, L., Clewell, H.J. III, Judson, R.S., Freeman, K., Bao, W, Sochaski, M.A., Chu T.-M., Black, M.B., Healy, E, Allen, B., Andersen M.E., Wolfinger, R.D., and Thomas R.S., "The Relative Impact of Incorporating Pharmacokinetics on Predicting in vivo Hazard and Mode-of-Action from High-Throughput in vitro Toxicity Assays" *Toxicological Sciences*, 132:327-346 (2013).
- Wetmore, B. A., Wambaugh, J. F., Allen, B., Ferguson, S. S., Sochaski, M. A., Setzer, R. W., Houck, K. A., Strope, C. L., Cantwell, K., Judson, R. S., LeCluyse, E., Clewell, H.J. III, Thomas, R.S., and Andersen, M. E. (2015). "Incorporating High-Throughput Exposure Predictions with Dosimetry-Adjusted In Vitro Bioactivity to Inform Chemical Toxicity Testing" *Toxicological Sciences*, kfv171.

## Examples

```
## Not run:  
get_lit_cheminfo()  
get_lit_cheminfo(info=c('CAS', 'MW'))  
  
## End(Not run)
```

---

get\_lit\_css

*Get literature Css*

---

## Description

This function retrieves a steady-state plasma concentration as a result of infusion dosing from the Wetmore et al. (2012) and (2013) publications and other literature.

## Usage

```
get_lit_css(chem.cas=NULL,chem.name=NULL,daily.dose=1,which.quantile=0.95,  
            species="Human",clearance.assay.conc=NULL,output.units="mg/L",  
            suppress.messages=F)
```

## Arguments

chem.name	Either the chemical name or the CAS number must be specified.
chem.cas	Either the cas number or the chemical name must be specified.
which.quantile	Which quantile from the SimCYP Monte Carlo simulation is requested. Can be a vector.
species	Species desired (either "Rat" or default "Human").
clearance.assay.conc	Concentration of chemical used in measuring intrinsic clearance data, 1 or 10 uM.
daily.dose	Total daily dose infused in units of mg/kg BW/day. Defaults to 1 mg/kg/day.
output.units	Returned units for function, defaults to mg/L but can also be uM (specify units = "uM").
suppress.messages	Whether or not the output message is suppressed.

## Author(s)

John Wambaugh

## References

Wetmore, B.A., Wambaugh, J.F., Ferguson, S.S., Sochaski, M.A., Rotroff, D.M., Freeman, K., Clewell, H.J., Dix, D.H., Andersen, M.E., Houck, K.A., Allen, B., Judson, R.S., Sing, R., Kavlock, R.J., Richard, A.M., and Thomas, R.S., "Integration of Dosimetry, Exposure and High-Throughput Screening Data in Chemical Toxicity Assessment," *Toxicological Sciences* 125 157-174 (2012)

Wetmore, B.A., Wambaugh, J.F., Ferguson, S.S., Li, L., Clewell, H.J. III, Judson, R.S., Freeman, K., Bao, W, Sochaski, M.A., Chu T.-M., Black, M.B., Healy, E, Allen, B., Andersen M.E., Wolfinger, R.D., and Thomas R.S., "The Relative Impact of Incorporating Pharmacokinetics on Predicting in vivo Hazard and Mode-of-Action from High-Throughput in vitro Toxicity Assays" *Toxicological Sciences*, 132:327-346 (2013).

Wetmore, B. A., Wambaugh, J. F., Allen, B., Ferguson, S. S., Sochaski, M. A., Setzer, R. W., Houck, K. A., Strope, C. L., Cantwell, K., Judson, R. S., LeCluyse, E., Clewell, H.J. III, Thomas, R.S., and Andersen, M. E. (2015). "Incorporating High-Throughput Exposure Predictions with Dosimetry-Adjusted In Vitro Bioactivity to Inform Chemical Toxicity Testing" *Toxicological Sciences*, kfv171.

## Examples

```
get_lit_css(chem.cas="34256-82-1")
```

```
get_lit_css(chem.cas="34256-82-1",species="Rat",which.quantile=0.5)
```

```
get_lit_css(chem.cas="80-05-7", daily.dose = 1,which.quantile = 0.5, output.units = "uM")
```

---

```
get_lit_oral_equiv      Get Literature Oral Equivalent Dose
```

---

## Description

This function converts a chemical plasma concentration to an oral equivalent dose using the values from the Wetmore et al. (2012) and (2013) publications and other literature.

## Usage

```
get_lit_oral_equiv(conc,chem.name=NULL,chem.cas=NULL,suppress.messages=F,
                   which.quantile=0.95,species="Human",input.units='uM',
                   output.units='mg',clearance.assay.conc=NULL,...)
```

## Arguments

conc	Bioactive in vitro concentration in units of specified input.units, default of uM.
chem.name	Either the chemical name or the CAS number must be specified.
chem.cas	Either the CAS number or the chemical name must be specified.
input.units	Units of given concentration, default of uM but can also be mg/L.

output.units Units of dose, default of 'mg' for mg/kg BW/ day or 'mol' for mol/ kg BW/ day.  
 suppress.messages Suppress output messages.  
 which.quantile Which quantile from the SimCYP Monte Carlo simulation is requested. Can be a vector. Papers include 0.05, 0.5, and 0.95 for humans and 0.5 for rats.  
 species Species desired (either "Rat" or default "Human").  
 clearance.assay.conc Concentration of chemical used in measureing intrinsic clearance data, 1 or 10 uM.  
 ... Additional parameters passed to get\_lit\_css.

**Value**

Equivalent dose in specified units, default of mg/kg BW/day.

**Author(s)**

John Wambaugh

**References**

Wetmore, B.A., Wambaugh, J.F., Ferguson, S.S., Sochaski, M.A., Rotroff, D.M., Freeman, K., Clewell, H.J., Dix, D.H., Andersen, M.E., Houck, K.A., Allen, B., Judson, R.S., Sing, R., Kavlock, R.J., Richard, A.M., and Thomas, R.S., "Integration of Dosimetry, Exposure and High-Throughput Screening Data in Chemical Toxicity Assessment," *Toxicological Sciences* 125 157-174 (2012)

Wetmore, B.A., Wambaugh, J.F., Ferguson, S.S., Li, L., Clewell, H.J. III, Judson, R.S., Freeman, K., Bao, W, Sochaski, M.A., Chu T.-M., Black, M.B., Healy, E, Allen, B., Andersen M.E., Wolfinger, R.D., and Thomas R.S., "The Relative Impact of Incorporating Pharmacokinetics on Predicting in vivo Hazard and Mode-of-Action from High-Throughput in vitro Toxicity Assays" *Toxicological Sciences*, 132:327-346 (2013).

Wetmore, B. A., Wambaugh, J. F., Allen, B., Ferguson, S. S., Sochaski, M. A., Setzer, R. W., Houck, K. A., Strope, C. L., Cantwell, K., Judson, R. S., LeCluyse, E., Clewell, H.J. III, Thomas, R.S., and Andersen, M. E. (2015). "Incorporating High-Throughput Exposure Predictions with Dosimetry-Adjusted In Vitro Bioactivity to Inform Chemical Toxicity Testing" *Toxicological Sciences*, kfv171.

**Examples**

```
table <- NULL
for(this.cas in sample(get_lit_cheminfo(),50)) table <- rbind(table,cbind(
as.data.frame(this.cas),as.data.frame(get_lit_oral_equiv(conc=1,chem.cas=this.cas))))
```

```
get_lit_oral_equiv(0.1,chem.cas="34256-82-1")
```

```
get_lit_oral_equiv(0.1,chem.cas="34256-82-1",which.quantile=c(0.05,0.5,0.95))
```

---

get\_rblood2plasma      *Get ratio of the blood concentration to the plasma concentration.*

---

### Description

This function retrieves the in vivo ratio of the blood concentration to the plasma concentration.

### Usage

```
get_rblood2plasma(chem.name=NULL, chem.cas=NULL, species="Human", default.to.human=F)
```

### Arguments

chem.name      Either the chemical name or the CAS number must be specified.  
chem.cas      Either the CAS number or the chemical name must be specified.  
species      Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").  
default.to.human      Substitutes missing animal values with human values if true.

### Details

A value of NA is returned when the requested value is unavailable. Values are retrieved from chem.physical\_and\_invitro.data.

### Author(s)

Robert Pearce

### Examples

```
get_rblood2plasma(chem.name="Bisphenol A")  
get_rblood2plasma(chem.name="Bisphenol A", species="Rat")
```

---

get\_weight\_class      *Given vectors of age, BMI, recumbent length, weight, and gender, categorizes weight classes using CDC and WHO categories.*

---

### Description

Given vectors of age, BMI, recumbent length, weight, and gender, categorizes weight classes using CDC and WHO categories.

### Usage

```
get_weight_class(age_years, age_months, bmi, recumlen, weight, gender)
```

**Arguments**

age_years	A vector of ages in years.
age_months	A vector of ages in months.
bmi	A vector of BMIs.
recumlen	A vector of heights or recumbent lengths in cm.
weight	A vector of body weights in kg.
gender	A vector of genders (as 'Male' or 'Female').

**Value**

A character vector of weight classes. Each element will be one of 'Underweight', 'Normal', 'Overweight', or 'Obese'.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

hematocrit\_infants      *Predict hematocrit in infants under 1 year old.*

---

**Description**

For infants under 1 year, hematocrit was not measured in NHANES. Assume a log-normal distribution where plus/minus 1 standard deviation of the underlying normal distribution is given by the reference range. Draw hematocrit values from these distributions by age.

**Usage**

```
hematocrit_infants(age_months)
```

**Arguments**

age_months	Vector of ages in months; all must be $\leq 12$ .
------------	---

**Details**

Age	Reference range
<1 month	31-49
1-6 months	29-42
7-12 months	33-38



**Value**

Vector of hematocrit percentages corresponding to the input vector of ages.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

howgate

*Howgate 2006*

---

**Description**

This data set is only used in Vignette 5.

**Usage**

howgate

---

httkpop

*httkpop: Virtual population generator for HTTK.*

---

**Description**

The httkpop package generates virtual population physiologies for use in population TK.

**Main function to generate a population**

If you just want to generate a table of (chemical-independent) population physiology parameters, use [httkpop\\_generate](#).

**Using HTTK-Pop with HTTK**

To generate a population and then run an HTTK model for that population, the workflow is as follows:

1. Generate a population using [httkpop\\_generate](#).
2. For a given HTTK chemical and general model, convert the population data to corresponding sets of HTTK model parameters using [get\\_httk\\_params](#).

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

httkpop_bio	<i>Convert HTKK-Pop-generated parameters to HTKK physiological parameters</i>
-------------	---

---

**Description**

Convert HTKK-Pop-generated parameters to HTKK physiological parameters

**Usage**

```
httkpop_bio(indiv_dt)
```

**Arguments**

indiv\_dt      The data.table object returned by httkpop\_generate()

**Value**

A data.table with the physiological parameters expected by any HTKK model, including body weight (BW), hematocrit, tissue volumes per kg body weight, tissue flows as fraction of CO, CO per (kg BW)<sup>3/4</sup>, GFR per (kg BW)<sup>3/4</sup>, portal vein flow per (kg BW)<sup>3/4</sup>, and liver density.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

 httkpop\_direct\_resample

*Generate a virtual population by directly resampling the NHANES data.*

---

## Description

Generate a virtual population by directly resampling the NHANES data.

## Usage

```
httkpop_direct_resample(nsamp = NULL, gendernum = NULL,
  agelim_years = NULL, agelim_months = NULL,
  weight_category = c("Underweight", "Normal", "Overweight", "Obese"),
  gfr_category = c("Normal", "Kidney Disease", "Kidney Failure"),
  reths = c("Mexican American", "Other Hispanic", "Non-Hispanic White",
    "Non-Hispanic Black", "Other"))
```

## Arguments

nsamp	The desired number of individuals in the virtual population. nsamp need not be provided if gendernum is provided.
gendernum	Optional: A named list giving the numbers of male and female individuals to include in the population, e.g. <code>list(Male=100,Female=100)</code> . Default is NULL, meaning both males and females are included, in their proportions in the NHANES data. If both nsamp and gendernum are provided, they must agree (i.e., nsamp must be the sum of gendernum).
agelim_years	Optional: A two-element numeric vector giving the minimum and maximum ages (in years) to include in the population. Default is <code>c(0,79)</code> . If agelim_years is provided and agelim_months is not, agelim_years will override the default value of agelim_months.
agelim_months	Optional: A two-element numeric vector giving the minimum and maximum ages (in months) to include in the population. Default is <code>c(0, 959)</code> , equivalent to the default agelim_years. If agelim_months is provided and agelim_years is not, agelim_months will override the default values of agelim_years.
weight_category	Optional: The weight categories to include in the population. Default is <code>c('Underweight', 'Normal', 'Overweight', 'Obese')</code> . User-supplied vector must contain one or more of these strings.
gfr_category	The kidney function categories to include in the population. Default is <code>c('Normal', 'Kidney Disease', 'Kidney Failure')</code> , to include all kidney function levels.
reths	Optional: a character vector giving the races/ethnicities to include in the population. Default is <code>c('Mexican American', 'Other Hispanic', 'Non-Hispanic White', 'Non-Hispanic Black', 'Other')</code> , to include all races and ethnicities in their proportions in the NHANES data. User-supplied vector must contain one or more of these strings.

**Value**

A data.table where each row represents an individual, and each column represents a demographic, anthropometric, or physiological parameter.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

httkpop\_direct\_resample\_inner

*Inner loop function called by httkpop\_direct\_resample.*

---

**Description**

Inner loop function called by httkpop\_direct\_resample.

**Usage**

```
httkpop_direct_resample_inner(nsamp, gendernum, agelim_months,
  agelim_years, reths, weight_category)
```

**Arguments**

nsamp	The desired number of individuals in the virtual population. nsamp need not be provided if gendernum is provided.
gendernum	Optional: A named list giving the numbers of male and female individuals to include in the population, e.g. list(Male=100,Female=100). Default is NULL, meaning both males and females are included, in their proportions in the NHANES data. If both nsamp and gendernum are provided, they must agree (i.e., nsamp must be the sum of gendernum).
agelim_months	Optional: A two-element numeric vector giving the minimum and maximum ages (in months) to include in the population. Default is c(0, 959), equivalent to the default agelim_years. If agelim_months is provided and agelim_years is not, agelim_months will override the default values of agelim_years.
agelim_years	Optional: A two-element numeric vector giving the minimum and maximum ages (in years) to include in the population. Default is c(0,79). If agelim_years is provided and agelim_months is not, agelim_years will override the default value of agelim_months.
reths	Optional: a character vector giving the races/ethnicities to include in the population. Default is c('Mexican American', 'Other Hispanic', 'Non-Hispanic White', 'Non-Hispanic Black'). If reths is provided, only the races/ethnicities in reths will be included to include all races and ethnicities in their proportions in the NHANES data. User-supplied vector must contain one or more of these strings.

weight\_category

Optional: The weight categories to include in the population. Default is `c('Underweight', 'Normal', 'Overweight', 'Obese')`. User-supplied vector must contain one or more of these strings.

### Value

A `data.table` where each row represents an individual, and each column represents a demographic, anthropometric, or physiological parameter.

### Author(s)

Caroline Ring

### References

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

httkpop_generate	<i>Generate a virtual population</i>
------------------	--------------------------------------

---

### Description

Generate a virtual population

### Usage

```
httkpop_generate(method, nsamp = NULL, gendernum = NULL,
  agelim_years = NULL, agelim_months = NULL,
  weight_category = c("Underweight", "Normal", "Overweight", "Obese"),
  gfr_category = c("Normal", "Kidney Disease", "Kidney Failure"),
  reths = c("Mexican American", "Other Hispanic", "Non-Hispanic White",
    "Non-Hispanic Black", "Other"))
```

### Arguments

method	The population-generation method to use. Either "virtual individuals" or "direct resampling." Short names may be used: "d" or "dr" for "direct resampling", and "v" or "vi" for "virtual individuals".
nsamp	The desired number of individuals in the virtual population. nsamp need not be provided if gendernum is provided.
gendernum	Optional: A named list giving the numbers of male and female individuals to include in the population, e.g. <code>list(Male=100, Female=100)</code> . Default is NULL, meaning both males and females are included, in their proportions in the NHANES data. If both nsamp and gendernum are provided, they must agree (i.e., nsamp must be the sum of gendernum).

agelim_years	Optional: A two-element numeric vector giving the minimum and maximum ages (in years) to include in the population. Default is <code>c(0,79)</code> . If only a single value is provided, both minimum and maximum ages will be set to that value; e.g. <code>agelim_years=3</code> is equivalent to <code>agelim_years=c(3,3)</code> . If <code>agelim_years</code> is provided and <code>agelim_months</code> is not, <code>agelim_years</code> will override the default value of <code>agelim_months</code> .
agelim_months	Optional: A two-element numeric vector giving the minimum and maximum ages (in months) to include in the population. Default is <code>c(0, 959)</code> , equivalent to the default <code>agelim_years</code> . If only a single value is provided, both minimum and maximum ages will be set to that value; e.g. <code>agelim_months=36</code> is equivalent to <code>agelim_months=c(36,36)</code> . If <code>agelim_months</code> is provided and <code>agelim_years</code> is not, <code>agelim_months</code> will override the default values of <code>agelim_years</code> .
weight_category	Optional: The weight categories to include in the population. Default is <code>c('Underweight', 'Normal', 'Overweight')</code> . User-supplied vector must contain one or more of these strings.
gfr_category	The kidney function categories to include in the population. Default is <code>c('Normal', 'Kidney Disease', 'End Stage Kidney Disease')</code> , to include all kidney function levels.
reths	Optional: a character vector giving the races/ethnicities to include in the population. Default is <code>c('Mexican American', 'Other Hispanic', 'Non-Hispanic White', 'Non-Hispanic Black')</code> , to include all races and ethnicities in their proportions in the NHANES data. User-supplied vector must contain one or more of these strings.

### Value

A `data.table` where each row represents an individual, and each column represents a demographic, anthropometric, or physiological parameter.

### Author(s)

Caroline Ring

### References

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

### Examples

```
## Not run:
#Simply generate a virtual population of 100 individuals,
#using the direct-resampling method
set.seed(42)
httkpop_generate(method='direct resampling', nsamp=100)
#Generate a population using the virtual-individuals method,
#including 80 females and 20 males,
#including only ages 20-65,
#including only Mexican American and
#Non-Hispanic Black individuals,
#including only non-obese individuals
```

```

httkpop_generate(method = 'virtual individuals',
  gendernum=list(Female=80,
  Male=20),
  agelim_years=c(20,65),
  reths=c('Mexican American',
  'Non-Hispanic Black'),
  weight_category=c('Underweight',
  'Normal',
  'Overweight'))

## End(Not run)

```

---

httkpop\_virtual\_indiv *Generate a virtual population by the virtual individuals method.*

---

## Description

Generate a virtual population by the virtual individuals method.

## Usage

```

httkpop_virtual_indiv(nsamp = NULL, gendernum = NULL,
  agelim_years = NULL, agelim_months = NULL,
  weight_category = c("Underweight", "Normal", "Overweight", "Obese"),
  gfr_category = c("Normal", "Kidney Disease", "Kidney Failure"),
  reths = c("Mexican American", "Other Hispanic", "Non-Hispanic White",
  "Non-Hispanic Black", "Other"))

```

## Arguments

nsamp	The desired number of individuals in the virtual population. nsamp need not be provided if gendernum is provided.
gendernum	Optional: A named list giving the numbers of male and female individuals to include in the population, e.g. list(Male=100,Female=100). Default is NULL, meaning both males and females are included, in their proportions in the NHANES data. If both nsamp and gendernum are provided, they must agree (i.e., nsamp must be the sum of gendernum).
agelim_years	Optional: A two-element numeric vector giving the minimum and maximum ages (in years) to include in the population. Default is c(0,79). If agelim_years is provided and agelim_months is not, agelim_years will override the default value of agelim_months.
agelim_months	Optional: A two-element numeric vector giving the minimum and maximum ages (in months) to include in the population. Default is c(0, 959), equivalent to the default agelim_years. If agelim_months is provided and agelim_years is not, agelim_months will override the default values of agelim_years.

weight_category	Optional: The weight categories to include in the population. Default is c('Underweight', 'Normal', 'Overweight'). User-supplied vector must contain one or more of these strings.
gfr_category	The kidney function categories to include in the population. Default is c('Normal', 'Kidney Disease', 'End Stage Renal Disease'). User-supplied vector must contain one or more of these strings.
reths	Optional: a character vector giving the races/ethnicities to include in the population. Default is c('Mexican American', 'Other Hispanic', 'Non-Hispanic White', 'Non-Hispanic Black'). User-supplied vector must contain one or more of these strings.

**Value**

A data.table where each row represents an individual, and each column represents a demographic, anthropometric, or physiological parameter.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

in.list	<i>Convenience Boolean (yes/no) functions to identify chemical membership in several key lists.</i>
---------	---

---

**Description**

These functions allow easy identification of whether or not a chemical CAS is included in various research projects. While it is our intent to keep these lists up-to-date, the information here is only for convenience and should not be considered to be definitive.

**Usage**

```
in.list(chem.cas=NULL, which.list="ToxCast")
is.nhanes(chem.cas)
is.nhanes.serum.parent(chem.cas)
is.nhanes.serum.analyte(chem.cas)
is.nhanes.blood.parent(chem.cas)
is.nhanes.blood.analyte(chem.cas)
is.nhanes.urine.parent(chem.cas)
is.nhanes.urine.analyte(chem.cas)
is.tox21(chem.cas)
is.toxcast(chem.cas)
is.expocast(chem.cas)
is.httk(chem.cas, species="Human", model="3compartments")
is.pharma(chem.cas)
```



**Arguments**

chem.cas	The Chemical Abstracts Service Registry Number (CAS-RN) corresponding to the chemical of interest.
which.list	A character string that can take the following values: "ToxCast", "Tox21", "ExpoCast", "NHANES", "NHANES.serum.parent", "NHANES.serum.analyte", "NHANES.blood.parent", "NHANES.urine.parent", "NHANES.urine.analyte"
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
model	Model used in calculation, 'pbtk' for the multiple compartment model, '1compartment' for the one compartment model, '3compartment' for three compartment model, '3compartments' for the three compartment model without partition coefficients, or 'schmitt' for chemicals with logP and fraction unbound (used in predict_partitioning_schmitt).

**Details**

Tox21: Toxicology in the 21st Century (Tox21) is a U.S. federal High Throughput Screening (HTS) collaboration among EPA, NIH, including National Center for Advancing Translational Sciences and the National Toxicology Program at the National Institute of Environmental Health Sciences, and the Food and Drug Administration. (Bucher et al., 2008)

ToxCast: The Toxicity Forecaster (ToxCast) is a HTS screening project led by the U.S. EPA to perform additional testing of a subset of Tox21 chemicals. (Judson et al. 2010)

ExpoCast: ExpoCast (Exposure Forecaster) is an U.S. EPA research project to generate tentative exposure estimates (e.g., mg/kg BW/day) for thousands of chemicals that have little other information using models and informatics. (Wambaugh et al. 2014)

NHANES: The U.S. Centers for Disease Control (CDC) National Health and Nutrition Examination Survey (NHANES) is an on-going survey to characterize the health and biometrics (e.g., weight, height) of the U.S. population. One set of measurements includes the quantification of xenobiotic chemicals in various samples (blood, serum, urine) of the thousands of surveyed individuals. (CDC, 2014)

**Value**

logical	A Boolean (1/0) value that is TRUE if the chemical is in the list.
---------	--

**Author(s)**

John Wambaugh

**References**

- Bucher, J. R. (2008). Guest Editorial: NTP: New Initiatives, New Alignment. *Environ Health Perspect* 116(1).
- Judson, R. S., Houck, K. A., Kavlock, R. J., Knudsen, T. B., Martin, M. T., Mortensen, H. M., Reif, D. M., Rotroff, D. M., Shah, I., Richard, A. M. and Dix, D. J. (2010). In Vitro Screening of Environmental Chemicals for Targeted Testing Prioritization: The ToxCast Project. *Environmental Health Perspectives* 118(4), 485-492.

Wambaugh, J. F., Wang, A., Dionisio, K. L., Frame, A., Egeghy, P., Judson, R. and Setzer, R. W. (2014). High Throughput Heuristics for Prioritizing Human Exposure to Environmental Chemicals. *Environmental Science & Technology*, 10.1021/es503583j.

CDC (2014). National Health and Nutrition Examination Survey. Available at: <http://www.cdc.gov/nchs/nhanes.htm>.

### Examples

```
httk.table <- get_cheminfo(info=c("CAS","Compound"))
httk.table[, "Rat"] <- ""
httk.table[, "NHANES"] <- ""
httk.table[, "Tox21"] <- ""
httk.table[, "ToxCast"] <- ""
httk.table[, "ExpoCast"] <- ""
httk.table[, "PBTk"] <- ""
# To make this example run quickly, this loop is only over the first fifty
# chemicals. To build a table with all available chemicals use:
# for (this.cas in httk.table$CAS)
for (this.cas in httk.table$CAS[1:50])
{
  this.index <- httk.table$CAS==this.cas
  if (is.nhanes(this.cas)) httk.table[this.index, "NHANES"] <- "Y"
  if (is.tox21(this.cas)) httk.table[this.index, "Tox21"] <- "Y"
  if (is.toxcast(this.cas)) httk.table[this.index, "ToxCast"] <- "Y"
  if (is.expocast(this.cas)) httk.table[this.index, "ExpoCast"] <- "Y"
  if (is.httk(this.cas, model="PBTk")) httk.table[this.index, "PBTk"] <- "Y"
  if (is.httk(this.cas, species="rat")) httk.table[this.index, "Rat"] <- "Y"
}
```

---

is_in_inclusive	<i>Checks whether a value, or all values in a vector, is within inclusive limits</i>
-----------------	--

---

### Description

Checks whether a value, or all values in a vector, is within inclusive limits

### Usage

```
is_in_inclusive(x, lims)
```

### Arguments

x	A numeric value, or vector of values.
lims	A two-element vector of (min, max) values for the inclusive limits. If x is a vector, lims may also be a two-column matrix with nrow=length(x) where the first column is lower limits and the second column is upper limits. If x is a vector and lims is a two-element vector, then each element of x will be checked against the same limits. If x is a vector and lims is a matrix, then each element of x will be checked against the limits given by the corresponding row of lims.

**Value**

A logical vector the same length as  $x$ , indicating whether each element of  $x$  is within the inclusive limits given by `lims`.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

johnson

*Johnson 2006*

---

**Description**

This data set is only used in Vignette 5.

**Usage**

johnson

---

kidney\_mass\_children *Predict kidney mass for children.*

---

**Description**

For individuals under age 18, predict kidney mass from weight, height, and gender. using equations from Ogiu et al.

**Usage**

kidney\_mass\_children(weight, height, gender)

**Arguments**

weight            Vector of weights in kg.  
 height            Vector of heights in cm.  
 gender            Vector of genders (either 'Male' or 'Female').

**Value**

A vector of kidney masses in kg.

---

liver\_mass\_children     *Predict liver mass for children.*

---

### Description

For individuals under 18, predict the liver mass from height, weight, and gender, using equations from Ogiu et al.

### Usage

```
liver_mass_children(height, weight, gender)
```

### Arguments

height	Vector of heights in cm.
weight	Vector of weights in kg.
gender	Vector of genders (either 'Male' or 'Female').

### Value

A vector of liver masses in kg.

---

load\_sipes2017     *Load data from Sipes et al 2017.*

---

### Description

This function returns an updated version of chem.physical\_and\_invitro.data that includes data predicted with Simulations Plus' ADMET predictor that was used in Sipes et al. 2017, included in admet.data.

### Usage

```
load_sipes2017(load.image=T, overwrite=F, target.env=.GlobalEnv)
```

### Arguments

load.image	If overwrite=TRUE (DEFAULT)) then the default HTTK chemical data plus the any new data/predictions from Sipes et al. (2017) will be quickly loaded. This is the same as load.image=F, but much faster, however any other data added by the user will be deleted.
------------	--

overwrite	Only matters if load.image=FALSE. If overwrite=TRUE then existing data in chem.physical_and_invitro.data will be replaced by any data/predictions in Sipes et al. (2017) that is for the same chemical and property. If overwrite=FALSE (DEFAULT) then new data for the same chemical and property are ignored. Funbound.plasma values of 0 (below limit of detection) are overwritten either way.
target.env	The environment where the new chem.physical_and_invitro.data is loaded. Defaults to global environment.

**Value**

data.frame	An updated version of chem.physical_and_invitro.data.
------------	---

**Author(s)**

Robert Pearce and John Wambaugh

**References**

Sipes, Nisha S., et al. "An intuitive approach for predicting potential human health risk with the Tox21 10k library." *Environmental Science & Technology* 51.18 (2017): 10786-10796.

**Examples**

```
## Not run:
chem.physical_and_invitro.data <- load_sipes2017()
chem.physical_and_invitro.data <- load_sipes2017(overwrite=T)

## End(Not run)
```

---

lump_tissues	<i>Lump tissue parameters</i>
--------------	-------------------------------

---

**Description**

This function takes the parameters from predict\_partitioning\_schmitt and lumps the partition coefficients along with the volumes and flows based on the given tissue list. It is useful in Monte Carlo simulation of individual partition coefficients when calculating the rest of body partition coefficient.

**Usage**

```
lump_tissues(Ktissue2pu.in, tissuelist=NULL, species="Human")
```

**Arguments**

Ktissue2pu.in	List of partition coefficients from predict_partitioning_schmitt.
tissuelist	Specifies compartment names and tissues groupings. Remaining tissues in tissue.data are lumped in the rest of the body.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").

**Value**

Krbc2pu	Ratio of concentration of chemical in red blood cells to unbound concentration in plasma.
Krest2pu	Ratio of concentration of chemical in rest of body tissue to unbound concentration in plasma.
Vrestc	Volume of the rest of the body per kg body weight, L/kg BW.
Vliverc	Volume of the liver per kg body weight, L/kg BW.
Qttotal.liverf	Fraction of cardiac output flowing to the gut and liver, i.e. out of the liver.
Qgutf	Fraction of cardiac output flowing to the gut.
Qkidneyf	Fraction of cardiac output flowing to the kidneys.

**Author(s)**

John Wambaugh

**Examples**

```
pcs <- predict_partitioning_schmitt(chem.name='bisphenola')
tissuelist <- list(liver=c("liver"),kidney=c("kidney"),lung=c("lung"),gut=c("gut")
,muscle.bone=c('muscle','bone'))
lump_tissues(pcs,tissuelist=tissuelist)
```

---

lung\_mass\_children      *Predict lung mass for children.*

---

**Description**

For individuals under 18, predict the liver mass from height, weight, and gender, using equations from Ogiu et al.

**Usage**

```
lung_mass_children(height,weight, gender)
```

**Arguments**

height	Vector of heights in cm.
weight	Vector of weights in kg.
gender	Vector of genders (either 'Male' or 'Female').

**Value**

A vector of lung masses in kg.

---

mcnally\_dt

*Reference tissue masses and flows from tables in McNally et al. 2014.*

---

### **Description**

Reference tissue masses, flows, and marginal distributions from McNally et al. 2014.

### **Usage**

mcnally\_dt

### **Format**

A data.table with variables:

tissue Body tissue

gender Gender: Male or Female

mass\_ref Reference mass in kg, from Reference Man

mass\_cv Coefficient of variation for mass

mass\_dist Distribution for mass: Normal or Log-normal

flow\_ref Reference flow in L/h, from Reference Man

flow\_cv Coefficient of variation for flow (all normally distributed)

height\_ref Reference heights (by gender)

CO\_ref Reference cardiac output by gender

flow\_frac Fraction of CO flowing to each tissue: flow\_ref/CO\_ref

### **Author(s)**

Caroline Ring

### **Source**

McNally K, Cotton R, Hogg A, Loizou G. "PopGen: A virtual human population generator." *Toxicology* 315, 70-85, 2004.

### **References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

monte\_carlo

*Monte Carlo for pharmacokinetic models***Description**

This function performs Monte Carlo to assess uncertainty and variability for toxicokinetic models.

**Usage**

```
monte_carlo(params,which.quantile=0.95,cv.params=NULL,censored.params=NULL,samples=1000,
            name.model='calc_analytic_css',output.col.model=NA,return.samples=F,...)
```

**Arguments**

- |                  |   |
|------------------|---|
| params           | All parameters needed by the function indicated by the argument "name.model". These parameters that are also listed in either cv.params or censored.params are sampled using Monte Carlo.   |
| which.quantile   | This argument specifies which quantiles are to be calculated. It can be a vector or a single value. It defaults to the 0.95 quantile (95%).   |
| cv.params        | The parameters listed in cv.params are sampled from a normal distribution that is truncated at zero. This argument should be a list of coefficients of variation (cv) for the normal distribution. Each entry in the list is named for a parameter in "params". New values are sampled with mean equal to the value in "params" and standard deviation equal to the mean times the cv.  |
| censored.params  | The parameters listed in censored.params are sampled from a normal distribution that is censored for values less than the limit of detection (specified separately for each parameter). This argument should be a list of sub-lists. Each sublist is named for a parameter in "params" and contains two elements: "cv" (coefficient of variation) and "LOD" (limit of detection), below which parameter values are censored. New values are sampled with mean equal to the value in "params" and standard deviation equal to the mean times the cv. Censored values are sampled on a uniform distribution between 0 and the limit of detection. |
| samples          | This argument is the number of samples to be generated for calculating quantiles.   |
| name.model       | This argument is a character vector giving the name of the model to be sampled. Defaults to 'calc_analytic_css'.  |
| output.col.model | If the evaluation of the function indicated by "model" returns a list, then model.output.col is the element from that list that is sampled and is used for calculating quantiles. Defaults to NA (i.e., the function returns a single value).   |
| return.samples   | Whether or not to return the vector containing the samples from the simulation instead of the selected quantile.  |
| ...              | Additional arguments passed to name.model.  |



**Author(s)**

John Wambaugh

**Examples**

```

#Example from httk jss paper:
## Not run:
library(ggplot2)
library(scales)
vary.params <- NULL
params <- parameterize_pbtck(chem.name = "Zoxamide")
for(this.param in names(subset(params,
names(params) != "Funbound.plasma"))){ vary.params[this.param] <- .2
censored.params <- list(Funbound.plasma = list(cv = 0.2, lod = 0.01))
set.seed(1)
out <- monte_carlo(params, cv.params = vary.params,
censored.params = censored.params, return.samples = T,
model = "pbtck", suppress.messages = T)
zoxamide <- ggplot(as.data.frame(out), aes(out)) +
geom_histogram(fill="blue", binwidth=1/6) + scale_x_log10() +
ylab("Number of Samples") + xlab("Steady State Concentration (uM)") +
theme(axis.text = element_text(size = 16),
axis.title = element_text(size = 16))
print(zoxamide)

# Fig 1 in Wambaugh et al. (2015) SimCYP vs. our predictions:

vary.params <- list(BW=0.3)
vary.params[["Vliverc"]]<-0.3
vary.params[["Qgfrc"]]<-0.3
vary.params[["Qttotal.liverc"]]<-0.3
vary.params[["million.cells.per.gliver"]]<-0.3
vary.params[["Clint"]]<-0.3
censored.params<-list(Funbound.plasma=list(cv=0.3,lod=0.01))

pValues <- get_cheminfo(c("Compound","CAS","Clint.pValue"))
pValues.rat <- get_cheminfo(c("Compound","CAS","Clint.pValue"),species="Rat")

Wetmore.table <- NULL
for (this.CAS in get_cheminfo(model="3compartmentss")){
  if (this.CAS %in% get_wetmore_cheminfo()){
    print(this.CAS)
    these.params <- parameterize_steadystate(chem.cas=this.CAS)
    if (these.params[["Funbound.plasma"]] == 0.0)
    {
      these.params[["Funbound.plasma"]] <- 0.005
    }
    these.params[["Fhеп.assay.correction"]] <- 1
    vLiver.human.values <- monte_carlo(these.params,

```

```

                                cv.params=vary.params,
                                censored.params=censored.params,
                                which.quantile=c(0.05,0.5,0.95),
                                output.units="mg/L",
                                model='3compartmentss',
                                suppress.messages=T,
                                well.stirred.correction=F,
                                Funbound.plasma.correction=F)

percentiles <- c("5","50","95")
for (this.index in 1:3)
{
  this.row <- as.data.frame(get_wetmore_css(chem.cas=this.CAS,
                                          which.quantile=as.numeric(percentiles[this.index])/100))
  this.row <- cbind(this.row, as.data.frame(vLiver.human.values[this.index]))
  this.row <- cbind(this.row, as.data.frame(percentiles[this.index]))
  this.row <- cbind(this.row, as.data.frame("Human"))
  this.row <- cbind(this.row, as.data.frame(this.CAS))
  this.row <- cbind(this.row, as.data.frame(pValues[pValues$CAS==this.CAS,
                                                  "Human.Clint.pValue"]<0.05))
  colnames(this.row) <- c("Wetmore", "Predicted", "Percentile", "Species",
                          "CAS", "Systematic")
  if (is.na(this.row["Systematic"])) this.row["Systematic"] <- F
  Wetmore.table <- Wetmore.table <- rbind(Wetmore.table,this.row)
}
}
}

scientific_10 <- function(x) {
  out <- gsub("1e", "10^", scientific_format()(x))
  out <- gsub("\\+", "", out)
  out <- gsub("10^01", "10", out)
  out <- parse(text=gsub("10^00", "1", out))
}

Fig1 <- ggplot(Wetmore.table, aes(Predicted,Wetmore,group = CAS)) +
  geom_line() +
  geom_point(aes(colour=factor(Percentile),shape=factor(Percentile))) +
  scale_colour_discrete(name="Percentile") +
  scale_shape_manual(name="Percentile", values=c("5"=21, "50"=22,"95"=24)) +
  scale_x_log10(expression(paste(C[ss]," Predicted (mg/L) with Refined Assumptions")),
                 label=scientific_10) +
  scale_y_log10(expression(paste(C[ss]," Wetmore ",italic("et al.")," (2012) (mg/L)")),
                 label=scientific_10) +
  geom_abline(intercept = 0, slope = 1,linetype="dashed")+
  theme_bw()+
  theme(legend.position="bottom", text = element_text(size=18))

print(Fig1)

Fig1a.fit <- lm(log(Wetmore) ~ log(Predicted)*Percentile, Wetmore.table)
## End(**Not run**)

```

```
## End(Not run)
```

---

nhanes_mec_svy	<i>Pre-processed NHANES data.</i>
----------------	-----------------------------------

---

## Description

NHANES data on demographics, anthropometrics, and some laboratory measures, cleaned and combined into a single data set.

## Usage

```
nhanes_mec_svy
```

## Format

A survey.design2 object, including masked cluster and strata. Variables are available as a data.table by nhanes\_mec\_svy\$variables. Variables are as described in NHANES Demographics and Examination documentation, with the exception of:

wtmec6yr 6-year sample weights for combining 3 cycles, computed by dividing 2-year sample weights by 3.

bxhtlenavg Average of height and recumbent length if both were measured; if only one was measured, takes value of the one that was measured.

logbxwt Natural log of measured body weight.

logbxhtlenavg Natural log of bxhtlenavg.

weight\_class One of Underweight, Normal, Overweight, or Obese. Assigned using methods in get\_weight\_class.

## Author(s)

Caroline Ring

## Source

[www.cdc.gov/nhanes/nhanes\\_questionnaires.htm](http://www.cdc.gov/nhanes/nhanes_questionnaires.htm)

## References

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." Environment International 106 (2017): 105-118

---

Obach2008

*Published Pharmacokinetic Parameters from Obach et al. 2008*

---

**Description**

This data set is used in Vignette 4 for steady state concentration.

**Usage**

Obach2008

**Format**

A data.frame containing 670 rows and 8 columns.

**References**

Obach, R. Scott, Franco Lombardo, and Nigel J. Waters. "Trend analysis of a database of intravenous pharmacokinetic parameters in humans for 670 drug compounds." *Drug Metabolism and Disposition* 36.7 (2008): 1385-1405.

---

onlyp

*NHANES Exposure Data*

---

**Description**

This data set is only used in Vignette 6.

**Usage**

onlyp

---

pancreas\_mass\_children

*Predict pancreas mass for children.*

---

### Description

For individuals under 18, predict the pancreas mass from height, weight, and gender, using equations from Ogiu et al.

### Usage

```
pancreas_mass_children(height, weight, gender)
```

### Arguments

height	Vector of heights in cm.
weight	Vector of weights in kg.
gender	Vector of genders (either 'Male' or 'Female').

### Value

A vector of pancreas masses in kg.

---

parameterize\_1comp      *Parameterize\_1comp*

---

### Description

This function initializes the parameters needed in the function solve\_1comp.

### Usage

```
parameterize_1comp(chem.cas=NULL, chem.name=NULL, species="Human",
  default.to.human=F, adjusted.funbound.plasma=T, regression=T,
  restrictive.clearance=T, well.stirred.correction=T,
  suppress.messages=F, clint.pvalue.threshold = 0.05)
```

### Arguments

chem.name	Either the chemical name or the CAS number must be specified.
chem.cas	Either the chemical name or the CAS number must be specified.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
default.to.human	Substitutes missing rat values with human values if true.

adjusted.funbound.plasma	Uses adjusted Funbound.plasma when set to TRUE along with volume of distribution calculated with this value.
regression	Whether or not to use the regressions in calculating partition coefficients in volume of distribution calculation.
restrictive.clearance	In calculating elimination rate and hepatic bioavailability, protein binding is not taken into account (set to 1) in liver clearance if FALSE.
well.stirred.correction	Uses correction in calculation of hepatic clearance for well-stirred model if TRUE. This assumes clearance relative to amount unbound in whole blood instead of plasma, but converted to use with plasma concentration.
suppress.messages	Whether or not to suppress messages.
clint.pvalue.threshold	Hepatic clearance for chemicals where the in vitro clearance assay result has a p-values greater than the threshold are set to zero.

**Value**

Vdist	Volume of distribution, units of L/kg BW.
Fgutabs	Fraction of the oral dose absorbed, i.e. the fraction of the dose that enters the gutlumen.
kelim	Elimination rate, units of 1/h.
hematocrit	Percent volume of red blood cells in the blood.
kgutabs	Rate chemical is absorbed, 1/h.
million.cells.per.gliver	Millions cells per gram of liver tissue.
MW	Molecular Weight, g/mol.
Rblood2plasma	The ratio of the concentration of the chemical in the blood to the concentration in the plasma. Not used in calculations but included for the conversion of plasma outputs.
hepatic.bioavailability	Fraction of dose remaining after first pass clearance, calculated from the corrected well-stirred model.
BW	Body Weight, kg.

**Author(s)**

John Wambaugh

**Examples**

```
parameters <- parameterize_1comp(chem.name='Bisphenol-A',species='Rat')
parameters <- parameterize_1comp(chem.cas='80-05-7',restrictive.clearance=FALSE,
                                species='rabbit',default.to.human=TRUE)
out <- solve_1comp(parameters=parameters)
```

---

parameterize\_3comp      *Parameterize\_3comp*

---

### Description

This function initializes the parameters needed in the function solve\_3comp.

### Usage

```
parameterize_3comp(chem.cas=NULL,chem.name=NULL,species="Human",
                  default.to.human=F,force.human.clint.fub = F,
                  clint.pvalue.threshold=0.05,adjusted.Funbound.plasma=T,
                  regression=T,suppress.messages=F)
```

### Arguments

chem.name	Either the chemical name or the CAS number must be specified.
chem.cas	Either the chemical name or the CAS number must be specified.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
default.to.human	Substitutes missing animal values with human values if true.
force.human.clint.fub	Forces use of human values for hepatic intrinsic clearance and fraction of unbound plasma if true.
clint.pvalue.threshold	Hepatic clearances with clearance assays having p-values greater than the threshold are set to zero.
adjusted.Funbound.plasma	Returns adjusted Funbound.plasma when set to TRUE along with partition coefficients calculated with this value.
regression	Whether or not to use the regressions in calculating partition coefficients.
suppress.messages	Whether or not the output message is suppressed.

### Value

BW	Body Weight, kg.
Clmetabolismc	Hepatic Clearance, L/h/kg BW.
Fgutabs	Fraction of the oral dose absorbed, i.e. the fraction of the dose that enters the gutlumen.
Funbound.plasma	Fraction of plasma that is not bound.
Fhep.assay.correction	The fraction of chemical unbound in hepatocyte assay using the method of Kilford et al. (2008)

hematocrit	Percent volume of red blood cells in the blood.
Kgut2pu	Ratio of concentration of chemical in gut tissue to unbound concentration in plasma.
Kliver2pu	Ratio of concentration of chemical in liver tissue to unbound concentration in plasma.
Krbc2pu	Ratio of concentration of chemical in red blood cells to unbound concentration in plasma.
Krest2pu	Ratio of concentration of chemical in rest of body tissue to unbound concentration in plasma.
million.cells.per.g.liver	Millions cells per gram of liver tissue.
MW	Molecular Weight, g/mol.
Qcardiacc	Cardiac Output, L/h/kg BW <sup>3/4</sup> .
Qgfrc	Glomerular Filtration Rate, L/h/kg BW <sup>3/4</sup> , volume of fluid filtered from kidney and excreted.
Qgutf	Fraction of cardiac output flowing to the gut.
Qliverf	Fraction of cardiac output flowing to the liver.
Rblood2plasma	The ratio of the concentration of the chemical in the blood to the concentration in the plasma.
Vgutc	Volume of the gut per kg body weight, L/kg BW.
Vliverc	Volume of the liver per kg body weight, L/kg BW.
Vrestc	Volume of the rest of the body per kg body weight, L/kg BW.

### Author(s)

Robert Pearce and John Wambaugh

### References

Kilford, P. J., Gertz, M., Houston, J. B. and Galetin, A. (2008). Hepatocellular binding of drugs: correction for unbound fraction in hepatocyte incubations using microsomal binding or drug lipophilicity data. *Drug Metabolism and Disposition* 36(7), 1194-7, 10.1124/dmd.108.020834.

### Examples

```
parameters <- parameterize_3comp(chem.name='Bisphenol-A',species='Rat')
parameters <- parameterize_3comp(chem.cas='80-05-7',
                                species='rabbit',default.to.human=TRUE)
out <- solve_3comp(parameters=parameters,plots=TRUE)
```



---

parameterize\_pbtck      *Parameterize\_PBTK*

---

### Description

This function initializes the parameters needed in the functions solve\_pbtck, calc\_css, and others using the multiple compartment model.

### Usage

```
parameterize_pbtck(chem.cas=NULL,chem.name=NULL,species="Human",default.to.human=F,
tissuelist=list(liver=c("liver"),kidney=c("kidney"),lung=c("lung"),gut=c("gut")),
force.human.clint.fub = F,clint.pvalue.threshold=0.05,
adjusted.funbound.plasma=T, regression=T, suppress.messages=F)
```

### Arguments

chem.name	Either the chemical name or the CAS number must be specified.
chem.cas	Either the chemical name or the CAS number must be specified.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
default.to.human	Substitutes missing animal values with human values if true (hepatic intrinsic clearance or fraction of unbound plasma).
tissuelist	Specifies compartment names and tissues groupings. Remaining tissues in tissue.data are lumped in the rest of the body. However, solve_pbtck only works with the default parameters.
force.human.clint.fub	Forces use of human values for hepatic intrinsic clearance and fraction of unbound plasma if true.
clint.pvalue.threshold	Hepatic clearance for chemicals where the in vitro clearance assay result has a p-values greater than the threshold are set to zero.
adjusted.funbound.plasma	Returns adjusted Funbound.plasma when set to TRUE along with partition coefficients calculated with this value.
regression	Whether or not to use the regressions in calculating partition coefficients.
suppress.messages	Whether or not the output message is suppressed.

### Value

BW	Body Weight, kg.
Clmetabolismc	Hepatic Clearance, L/h/kg BW.
Fgutabs	Fraction of the oral dose absorbed, i.e. the fraction of the dose that enters the gutlumen.

Funbound.plasma	Fraction of plasma that is not bound.
Fhеп.assay.correction	The fraction of chemical unbound in hepatocyte assay using the method of Kilford et al. (2008)
hematocrit	Percent volume of red blood cells in the blood.
Kgut2pu	Ratio of concentration of chemical in gut tissue to unbound concentration in plasma.
kgutabs	Rate that chemical enters the gut from gutlumen, 1/h.
Kkidney2pu	Ratio of concentration of chemical in kidney tissue to unbound concentration in plasma.
Kliver2pu	Ratio of concentration of chemical in liver tissue to unbound concentration in plasma.
Klung2pu	Ratio of concentration of chemical in lung tissue to unbound concentration in plasma.
Krbc2pu	Ratio of concentration of chemical in red blood cells to unbound concentration in plasma.
Krest2pu	Ratio of concentration of chemical in rest of body tissue to unbound concentration in plasma.
million.cells.per.gliver	Millions cells per gram of liver tissue.
MW	Molecular Weight, g/mol.
Qcardiac	Cardiac Output, L/h/kg BW <sup>3/4</sup> .
Qgfrс	Glomerular Filtration Rate, L/h/kg BW <sup>3/4</sup> , volume of fluid filtered from kidney and excreted.
Qgutf	Fraction of cardiac output flowing to the gut.
Qkidneyf	Fraction of cardiac output flowing to the kidneys.
Qliverf	Fraction of cardiac output flowing to the liver.
Rblood2plasma	The ratio of the concentration of the chemical in the blood to the concentration in the plasma from available_rblood2plasma.
Vartc	Volume of the arteries per kg body weight, L/kg BW.
Vgutс	Volume of the gut per kg body weight, L/kg BW.
Vkidneyс	Volume of the kidneys per kg body weight, L/kg BW.
Vliverс	Volume of the liver per kg body weight, L/kg BW.
Vlungс	Volume of the lungs per kg body weight, L/kg BW.
Vrestс	Volume of the rest of the body per kg body weight, L/kg BW.
Vvenc	Volume of the veins per kg body weight, L/kg BW.

**Author(s)**

John Wambaugh and Robert Pearce

## References

Kilford, P. J., Gertz, M., Houston, J. B. and Galetin, A. (2008). Hepatocellular binding of drugs: correction for unbound fraction in hepatocyte incubations using microsomal binding or drug lipophilicity data. *Drug Metabolism and Disposition* 36(7), 1194-7, 10.1124/dmd.108.020834.

## Examples

```
parameters <- parameterize_pbtck(chem.cas='80-05-7')

parameters <- parameterize_pbtck(chem.name='Bisphenol-A', species='Rat')

# Change the tissue lumping (note, these model parameters will not work with our current solver):
compartments <- list(liver=c("liver"), fast=c("heart", "brain", "muscle", "kidney"),
                    lung=c("lung"), gut=c("gut"), slow=c("bone"))
parameterize_pbtck(chem.name="Bisphenol a", species="Rat", default.to.human=TRUE,
                  tissuelist=compartments)
```

---

parameterize\_schmitt *Parameterize Schmitt's method.*

---

## Description

This function provides the necessary parameters to run `predict_partitioning_schmitt`, excluding the data in `tissue.data`.

## Usage

```
parameterize_schmitt(chem.cas=NULL, chem.name=NULL, species="Human",
                    default.to.human=F, force.human.fub=F)
```

## Arguments

<code>chem.name</code>	Either the chemical name or the CAS number must be specified.
<code>chem.cas</code>	Either the chemical name or the CAS number must be specified.
<code>species</code>	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
<code>default.to.human</code>	Substitutes missing fraction of unbound plasma with human values if true.
<code>force.human.fub</code>	Returns human fraction of unbound plasma in calculation for rats if true.

## Details

When `species` is specified as rabbit, dog, or mouse, the human unbound fraction is substituted.

`force.human.fub` calculates `Funbound.plasma.corrected` with the human lipid fractional volume in plasma.

**Value**

Funbound.plasma	corrected unbound fraction in plasma
unadjusted.Funbound.plasma	measured unbound fraction in plasma (0.005 if below limit of detection)
Pow	octanol:water partition coefficient (not log transformed)
pKa_Donor	compound H dissociation equilibrium constant(s)
pKa_Accept	compound H association equilibrium constant(s)
MA	phospholipid:water distribution coefficient, membrane affinity
Fprotein.plasma	protein fraction in plasma
plasma.pH	pH of the plasma

**Author(s)**

Robert Pearce

**Examples**

```
parameterize_schmitt(chem.name='bisphenola')
```

---

```
parameterize_steadystate
```

*Parameterize\_SteadyState*

---

**Description**

This function initializes the parameters needed in the functions `calc_mc_css`, `calc_mc_oral_equiv`, and `calc_analytic_css` for the three compartment steady state model ('3compartmentss').

**Usage**

```
parameterize_steadystate(chem.cas=NULL,chem.name=NULL,species="Human",
                        clint.pvalue.threshold=0.05,default.to.human=F,
                        human.clint.fub=F,adjusted.Funbound.plasma=T,
                        restrictive.clearance=T)
```

**Arguments**

chem.name	Either the chemical name or the CAS number must be specified.
chem.cas	Either the chemical name or the CAS number must be specified.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
clint.pvalue.threshold	Hepatic clearances with clearance assays having p-values greater than the threshold are set to zero.

default.to.human	Substitutes missing rat values with human values if true.
human.clint.fub	Uses human hepatic intrinsic clearance and fraction of unbound plasma in calculation of partition coefficients for rats if true.
adjusted.funbound.plasma	Returns adjusted Funbound.plasma when set to TRUE.
restrictive.clearance	In calculating hepatic.bioavailability, protein binding is not taken into account (set to 1) in liver clearance if FALSE.

**Value**

Clint	Hepatic Intrinsic Clearance, uL/min/10 <sup>6</sup> cells.
Fgutabs	Fraction of the oral dose absorbed, i.e. the fraction of the dose that enters the gutlumen.
Funbound.plasma	Fraction of plasma that is not bound.
Qtotall.liverc	Flow rate of blood exiting the liver, L/h/kg BW <sup>3/4</sup> .
Qgfrc	Glomerular Filtration Rate, L/h/kg BW <sup>3/4</sup> , volume of fluid filtered from kidney and excreted.
BW	Body Weight, kg
MW	Molecular Weight, g/mol
million.cells.per.gliver	Millions cells per gram of liver tissue.
Vliverc	Volume of the liver per kg body weight, L/kg BW.
liver.density	Liver tissue density, kg/L.
Fhep.assay.correction	The fraction of chemical unbound in hepatocyte assay using the method of Kilford et al. (2008)
hepatic.bioavailability	Fraction of dose remaining after first pass clearance, calculated from the corrected well-stirred model.

**Author(s)**

John Wambaugh

**Examples**

```
parameters <- parameterize_steadystate(chem.name='Bisphenol-A', species='Rat')
parameters <- parameterize_steadystate(chem.cas='80-05-7')
```

---

pc.data

*Partition Coefficient Data*

---

### **Description**

Measured rat in vivo partition coefficients and data for predicting them.

### **Usage**

pc.data

### **Format**

A data.frame.

### **Author(s)**

Jimena Davis and Robert Pearce

### **References**

Schmitt, W., General approach for the calculation of tissue to plasma partition coefficients. *Toxicology in Vitro*, 2008. 22(2): p. 457-467.

Schmitt, W., Corrigendum to:"General approach for the calculation of tissue to plasma partition coefficients"[*Toxicology in Vitro* 22 (2008) 457-467]. *Toxicology in Vitro*, 2008. 22(6): p. 1666.

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Rodgers, T. and M. Rowland, Physiologically based pharmacokinetic modelling 2: predicting the tissue distribution of acids, very weak bases, neutrals and zwitterions. *Journal of pharmaceutical sciences*, 2006. 95(6): p. 1238-1257.

Rodgers, T., D. Leahy, and M. Rowland, Physiologically based pharmacokinetic modeling 1: predicting the tissue distribution of moderate-to-strong bases. *Journal of pharmaceutical sciences*, 2005. 94(6): p. 1259-1276.

Rodgers, T., D. Leahy, and M. Rowland, Tissue distribution of basic drugs: Accounting for enantiomeric, compound and regional differences amongst beta-blocking drugs in rat. *Journal of pharmaceutical sciences*, 2005. 94(6): p. 1237-1248.

Gueorguieva, I., et al., Development of a whole body physiologically based model to characterise the pharmacokinetics of benzodiazepines. 1: Estimation of rat tissue-plasma partition ratios. *Journal of pharmacokinetics and pharmacodynamics*, 2004. 31(4): p. 269-298.

Poulin, P., K. Schoenlein, and F.P. Theil, Prediction of adipose tissue: plasma partition coefficients for structurally unrelated drugs. *Journal of pharmaceutical sciences*, 2001. 90(4): p. 436-447.

Bjorkman, S., Prediction of the volume of distribution of a drug: which tissue-plasma partition coefficients are needed? *Journal of pharmacy and pharmacology*, 2002. 54(9): p. 1237-1245.

Yun, Y. and A. Edginton, Correlation-based prediction of tissue-to-plasma partition coefficients using readily available input parameters. *Xenobiotica*, 2013. 43(10): p. 839-852.

Uchimura, T., et al., Prediction of human blood-to-plasma drug concentration ratio. *Biopharmaceutics & drug disposition*, 2010. 31(5-6): p. 286-297.

---

physiology.data

*Species-specific physiology parameters*

---

### **Description**

This data set contains values from Davies and Morris (1993) necessary to parameterize a toxicokinetic model for human, mouse, rat, dog, or rabbit. The temperature for each species are taken from Robertshaw et al. (2004), Gordon (1993), and Stammers(1926).

### **Usage**

physiology.data

### **Format**

A data.frame containing 11 rows and 7 columns.

### **Author(s)**

John Wambaugh and Nisha Sipes

### **Source**

Wambaugh, John F., et al. "Toxicokinetic triage for environmental chemicals." *Toxicological Sciences* (2015): 228-237.

### **References**

Davies, B. and Morris, T. (1993). *Physiological Parameters in Laboratory Animals and Humans*. *Pharmaceutical Research* 10(7), 1093-1095, 10.1023/a:1018943613122. Anderson and Holford (2009) Robertshaw, D., *Temperature Regulation and Thermal Environment*, in *Dukes' Physiology of Domestic Animals*, 12th ed., Reece W.O., Ed. Copyright 2004 by Cornell University. Stammers (1926) *The blood count and body temperature in normal rats* Gordon (1993) *Temperature Regulation in Laboratory Rodents*

---

predict\_partitioning\_schmitt

*Predict partition coefficients using the method from Schmitt (2008).*

---

### Description

This function implements the method from Schmitt (2008) in predicting the tissue to unbound plasma partition coefficients from for the tissues contained in the tissue.data table.

### Usage

```
predict_partitioning_schmitt(chem.name=NULL,chem.cas=NULL,species="Human",
                             default.to.human=F,parameters=NULL,
                             adjusted.Funbound.plasma=T, regression=T,
                             regression.list=c('brain','adipose','gut','heart','kidney',
                                                'liver','lung','muscle','skin','spleen','bone'),
                             tissues=NULL)
```

### Arguments

chem.name	Either the chemical name or the CAS number must be specified.
chem.cas	Either the chemical name or the CAS number must be specified.
species	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
default.to.human	Substitutes missing animal values with human values if true (hepatic intrinsic clearance or fraction of unbound plasma).
parameters	Chemical parameters from the parameterize_schmitt function, overrides chem.name and chem.cas.
adjusted.Funbound.plasma	Whether or not to use Funbound.plasma adjustment.
regression	Whether or not to use the regressions. Regressions are used by default.
regression.list	Tissues to use regressions on.
tissues	Vector of desired partition coefficients. Returns all by default.

### Details

A separate regression is used when adjusted.Funbound.plasma is FALSE.

A regression is used for membrane affinity when not provided. The regressions for correcting each tissue are performed on tissue plasma partition coefficients ( $K_{tissue2pu} * Funbound.plasma$ ) calculated with the corrected Funbound.plasma value and divided by this value to get  $K_{tissue2pu}$ . Thus the regressions should be used with the corrected Funbound.plasma.

The red blood cell regression can be used but is not by default because of the span of the data used, reducing confidence in the regression for higher and lower predicted values.

Human tissue volumes are used for species other than Rat.



**Value**

Returns tissue to unbound plasma partition coefficients for each tissue.

**Author(s)**

Robert Pearce

**Examples**

```
predict_partitioning_schmitt(chem.name='ibuprofen', regression=FALSE)
```

---

rfun

*Randomly draws from a one-dimensional KDE*

---

**Description**

Randomly draws from a one-dimensional KDE

**Usage**

```
rfun(n, fhat)
```

**Arguments**

n	Number of samples to draw
fhat	A list with elements x, w, and h (h is the KDE bandwidth).

**Value**

A vector of n samples from the KDE fhat

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

`r_left_censored_norm` *Returns draws from a normal distribution with a lower censoring limit of lod (limit of detection)*

---

**Description**

Returns draws from a normal distribution with a lower censoring limit of lod (limit of detection)

**Usage**

```
r_left_censored_norm(n, mean = 0, sd = 1, lod = 0.005, lower = 0,
  upper = 1)
```

**Arguments**

<code>n</code>	Number of samples to take
<code>mean</code>	Mean of censored distribution. Default 0.
<code>sd</code>	Standard deviation of censored distribution. Default 1.
<code>lod</code>	Bound below which to censor. Default 0.005.
<code>lower</code>	Lower bound on censored distribution. Default 0.
<code>upper</code>	Upper bound on censored distribution. Default 1.

**Value**

A vector of samples from the specified censored distribution.

---

<code>sipes2017</code>	<i>Sipes et al. 2017 data</i>
------------------------	-------------------------------

---

**Description**

This table includes data predicted with Simulations Plus' ADMET predictor, used in `load_sipes2017`, that was used in Sipes et al. 2017. The column names are equivalent to those of `chem.physical_and_invitro.data`.

**Usage**

```
sipes2017
```

**Format**

```
data.frame
```

**Author(s)**

Nisha Sipes

**Source**

ADMET, Simulations Plus

**References**

Sipes, Nisha S., et al. "An Intuitive Approach for Predicting Potential Human Health Risk with the Tox21 10k Library." *Environmental Science & Technology* 51.18 (2017): 10786-10796.

---

sipes2017.table	<i>Physico-chemical properties and toxicokinetics, measured values and Sipes et al. (2017)</i>
-----------------	--

---

**Description**

This data set contains the necessary information to make basic, high-throughput toxicokinetic (HTTK) predictions for compounds, including Funbound.plasma, molecular weight (g/mol), logP, logMA (membrane affinity), intrinsic clearance(uL/min/10<sup>6</sup> cells), and pKa. These data have been compiled from multiple sources, and can be used to parameterize a variety of toxicokinetic models. The Sipes et al. (2017) predictions have been added.

**Usage**

chem.physical\_and\_invitro.data

**Format**

A data.frame containing 9211 rows and 47 columns.

**Author(s)**

John Wambaugh

**Source**

Wambaugh, John F., et al. "Toxicokinetic triage for environmental chemicals." *Toxicological Sciences* (2015): 228-237.

**References**

DSStox database ([http:// www.epa.gov/ncct/dsstox](http://www.epa.gov/ncct/dsstox))

EPI Suite, <http://www.epa.gov/opptintr/exposure/pubs/episuite.htm>

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Predicting In Vivo Hazard and Mode of Action from High-Throughput In Vitro Toxicity Assays. *Toxicological Sciences* 132(2), 327-346, 10.1093/toxsci/kft012.

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---

skeletal\_muscle\_mass *Predict skeletal muscle mass.*

---

### Description

Predict skeletal muscle mass from age, height, and gender.

### Usage

```
skeletal_muscle_mass(smm, age_years, height, gender)
```

### Arguments

smm	Vector of allometrically-scaled skeletal muscle masses.
age_years	Vector of ages in years.
height	Vector of heights in cm.
gender	Vector of genders, either 'Male' or 'Female.'

### Details

For individuals over age 18, use allometrically-scaled muscle mass with an age-based scaling factor, to account for loss of muscle mass with age (Janssen et al. 2000). For individuals under age 18, use [skeletal\\_muscle\\_mass\\_children](#).

### Value

Vector of skeletal muscle masses in kg.

### See Also

[skeletal\\_muscle\\_mass\\_children](#)

---

skeletal\_muscle\_mass\_children

*Predict skeletal muscle mass for children.*

---

**Description**

For individuals under age 18, predict skeletal muscle mass from gender and age, using a nonlinear equation from J Cachexia Sarcopenia Muscle 2012 3:25-29.

**Usage**

skeletal\_muscle\_mass\_children(gender, age\_years)

**Arguments**

gender            Vector of genders (either 'Male' or 'Female').  
age\_years        Vector of ages in years.

**Value**

Vector of skeletal muscle masses in kg.

---

skin\_mass\_bosgra        *Predict skin mass.*

---

**Description**

Using equation from Bosgra et al. 2012, predict skin mass from body surface area.

**Usage**

skin\_mass\_bosgra(BSA)

**Arguments**

BSA                Vector of body surface areas in cm<sup>2</sup>.

**Value**

Vector of skin masses in kg.

---

 solve\_1comp

*Solve one compartment TK model*


---

## Description

This function solves for the amount or concentration of a chemical in plasma for a one compartment model as a function of time based on the dose and dosing frequency.

## Usage

```
solve_1comp(chem.cas=NULL,chem.name=NULL,times=NULL,parameters=NULL,daily.dose=1,
dose=NULL,doses.per.day=NULL, days=10,tsteps = 4, suppress.messages=F,
species='Human',output.units='uM',plots=F,initial.values=NULL,
iv.dose=F,method="lsoda",rtol=1e-8,atol=1e-12,
default.to.human=F,dosing.matrix=NULL,recalc.elimination=F,
adjusted.funbound.plasma=T,regression=T,restrictive.clearance=T,
well.stirred.correction=T,...)
```

## Arguments

chem.name	Either the chemical name, CAS number, or the parameters must be specified.
chem.cas	Either the chemical name, CAS number, or the parameters must be specified.
times	Optional time sequence for specified number of days.
parameters	Chemical parameters from parameterize_1comp function, overrides chem.name and chem.cas.
days	Length of the simulation.
tsteps	The number time steps per hour.
daily.dose	Total daily dose, mg/kg BW.
dose	Amount of a single dose, mg/kg BW. Overwrites daily.dose.
doses.per.day	Number of doses per day.
species	Species desired (either "Rat", "Rabbit", "Dog", or default "Human").
iv.dose	Simulates a single i.v. dose if true.
output.units	Desired units (either "mg/L", "mg", "umol", or default "uM").
initial.values	Vector containing the initial concentrations or amounts of the chemical in specified tissues with units corresponding to output.units. Defaults are zero.
suppress.messages	Whether or not the output message is suppressed.
plots	Plots all outputs if true.
method	Method used by integrator (deSolve).
rtol	Argument passed to integrator (deSolve).
atol	Argument passed to integrator (deSolve).

<code>default.to.human</code>	Substitutes missing rat values with human values if true.
<code>dosing.matrix</code>	Vector of dosing times or a matrix consisting of two columns or rows named "dose" and "time" containing the time and amount, in mg/kg BW, of each dose.
<code>recalc.elimination</code>	Whether or not to recalculate the elimination rate.
<code>adjusted.funbound.plasma</code>	Uses adjusted <code>Funbound.plasma</code> when set to TRUE along with volume of distribution calculated with this value.
<code>regression</code>	Whether or not to use the regressions in calculating partition coefficients in volume of distribution calculation.
<code>restrictive.clearance</code>	In calculating elimination rate, protein binding is not taken into account (set to 1) in liver clearance if FALSE.
<code>well.stirred.correction</code>	Uses correction in calculation of hepatic clearance for well-stirred model if TRUE. This assumes clearance relative to amount unbound in whole blood instead of plasma, but converted to use with plasma concentration.
<code>...</code>	Additional arguments passed to the integrator.

## Details

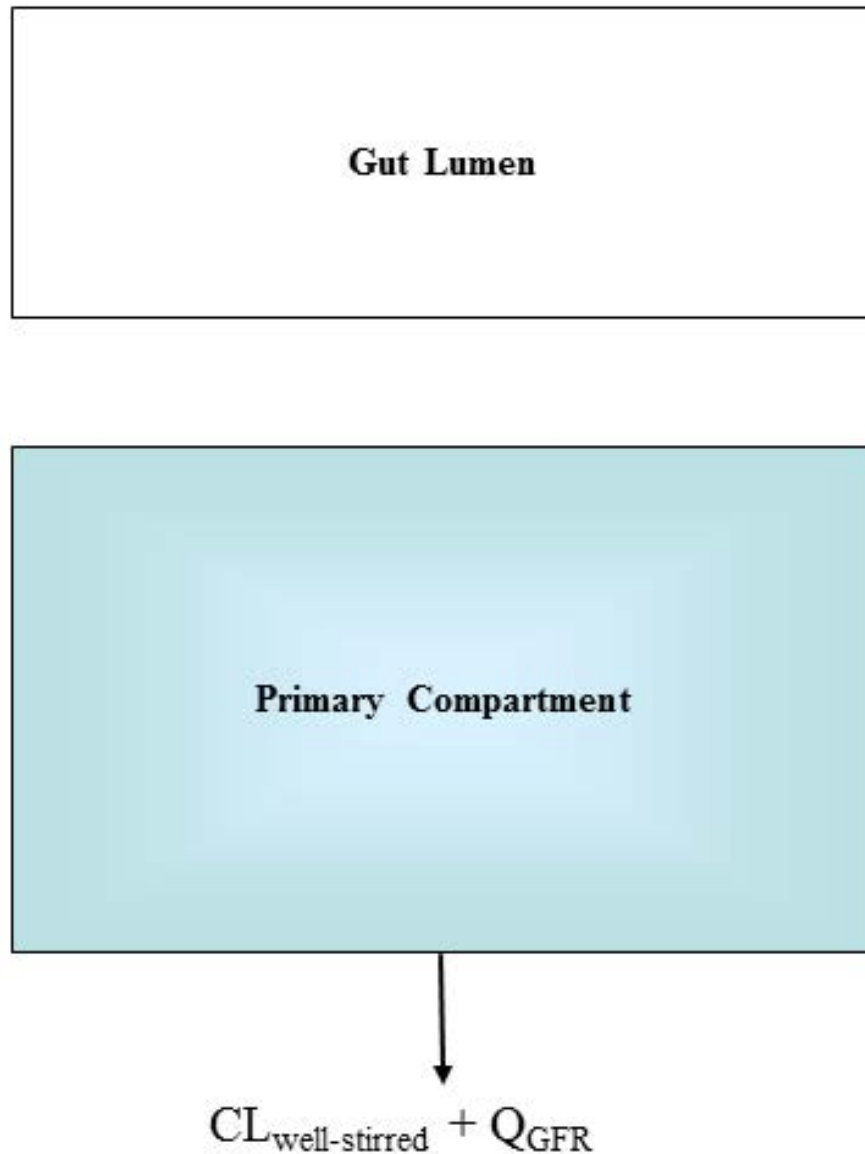
Note that the model parameters have units of hours while the model output is in days.

Default value of NULL for `doses.per.day` solves for a single dose.

AUC is area under plasma concentration curve.

Model Figure





altalt

**Value**

A matrix with a column for time(in days) and a column for the compartment and the area under the curve (concentration only).

**Author(s)**

Robert Pearce

## References

Pearce, Robert G., et al. "Httk: R package for high-throughput toxicokinetics." Journal of statistical software 79.4 (2017): 1.

## Examples

```
solve_1comp(chem.name='Bisphenol-A',days=1)
params <- parameterize_1comp(chem.cas="80-05-7")
solve_1comp(parameters=params)
```

---

solve\_3comp

*Solve\_3comp*

---

## Description

This function solves for the amounts or concentrations of a chemical in different tissues as functions of time based on the dose and dosing frequency. It uses a three compartment model with partition coefficients.

## Usage

```
solve_3comp(chem.name = NULL, chem.cas = NULL, times=NULL,
            parameters=NULL, days=10, tsteps = 4, daily.dose = 1,dose=NULL,
            doses.per.day=NULL, initial.values=NULL,plots=F, suppress.messages=F,
            species="Human", iv.dose=F,output.units='uM',
            method="lsoda",rtol=1e-8,
            atol=1e-12,default.to.human=F,recalc.blood2plasma=F,
            recalc.clearance=F,dosing.matrix=NULL,adjusted.Funbound.plasma=T,
            regression=T,restrictive.clearance = T,...)
```

## Arguments

chem.name	Either the chemical name, CAS number, or the parameters must be specified.
chem.cas	Either the chemical name, CAS number, or the parameters must be specified.
times	Optional time sequence for specified number of days. The dosing sequence begins at the beginning of times.
parameters	Chemical parameters from parameterize_3comp function, overrides chem.name and chem.cas.
days	Length of the simulation.
tsteps	The number time steps per hour.
daily.dose	Total daily dose, mg/kg BW.
dose	Amount of a single dose, mg/kg BW. Overwrites daily.dose.
doses.per.day	Number of doses per day.
initial.values	Vector containing the initial concentrations or amounts of the chemical in specified tissues with units corresponding to output.units. Defaults are zero.

<code>plots</code>	Plots all outputs if true.
<code>suppress.messages</code>	Whether or not the output message is suppressed.
<code>species</code>	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
<code>iv.dose</code>	Simulates a single i.v. dose if true.
<code>output.units</code>	Desired units (either "mg/L", "mg", "umol", or default "uM").
<code>method</code>	Method used by integrator (deSolve).
<code>rtol</code>	Argument passed to integrator (deSolve).
<code>atol</code>	Argument passed to integrator (deSolve).
<code>default.to.human</code>	Substitutes missing animal values with human values if true (hepatic intrinsic clearance or fraction of unbound plasma).
<code>recalc.blood2plasma</code>	Recalculates the ratio of the amount of chemical in the blood to plasma using the input parameters, calculated with hematocrit, Funbound.plasma, and Krbc2pu.
<code>recalc.clearance</code>	Recalculates the the hepatic clearance (Clmetabolism) with new million.cells.per.glivex parameter.
<code>dosing.matrix</code>	Vector of dosing times or a matrix consisting of two columns or rows named "dose" and "time" containing the time and amount, in mg/kg BW, of each dose.
<code>adjusted.Funbound.plasma</code>	Uses adjusted Funbound.plasma when set to TRUE along with partition coefficients calculated with this value.
<code>regression</code>	Whether or not to use the regressions in calculating partition coefficients.
<code>restrictive.clearance</code>	Protein binding not taken into account (set to 1) in liver clearance if FALSE.
<code>...</code>	Additional arguments passed to the integrator.

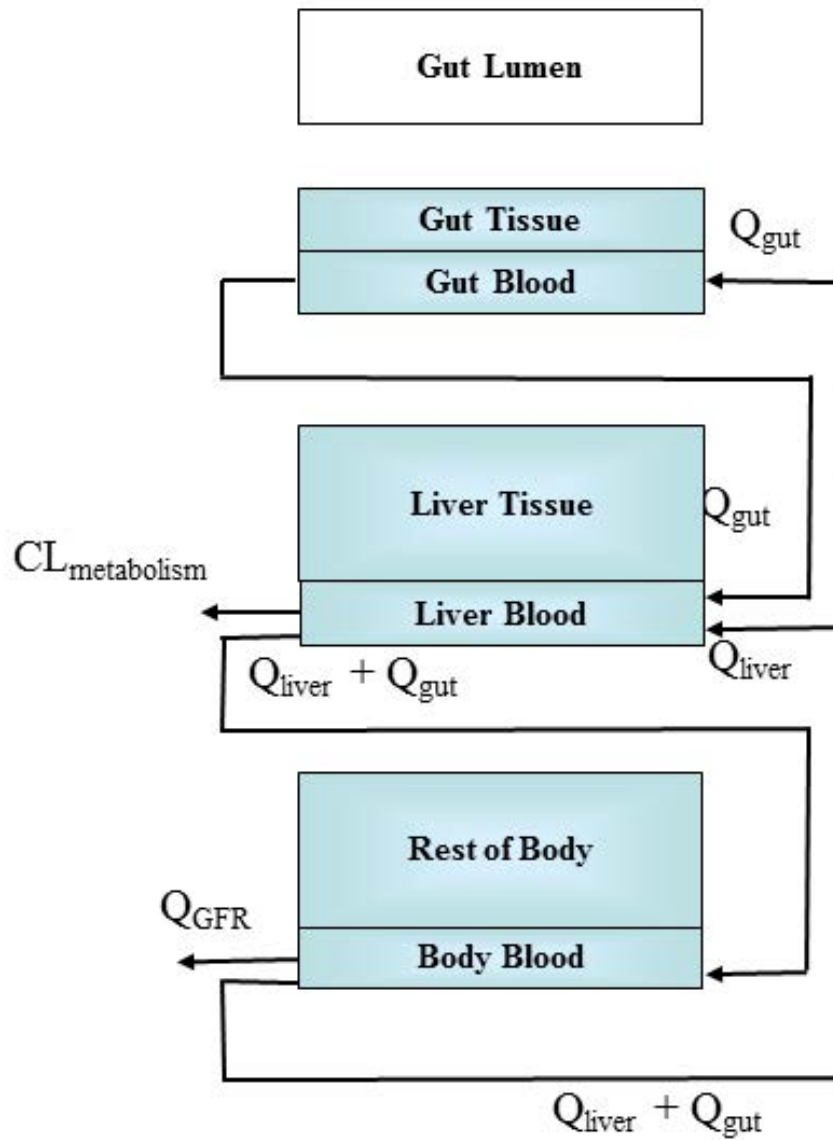
## Details

Note that the model parameters have units of hours while the model output is in days.

Default of NULL for `doses.per.day` solves for a single dose.

The compartments used in this model are the gutlumen, gut, liver, and rest-of-body, with the plasma equivalent to the liver plasma.

Model Figure



altalt

**Value**

A matrix of class `deSolve` with a column for time(in days) and each compartment, the plasma concentration, area under the curve, and a row for each time point.

**Author(s)**

John Wambaugh and Robert Pearce

## References

Pearce, Robert G., et al. "Httk: R package for high-throughput toxicokinetics." *Journal of statistical software* 79.4 (2017): 1.

## Examples

```
solve_3comp(chem.name='Bisphenol-A',doses.per.day=2,dose=.5,days=1,tsteps=2)
params <-parameterize_3comp(chem.cas="80-05-7")
solve_3comp(parameters=params)
```

---

solve\_pbt

*Solve\_PBT*

---

## Description

This function solves for the amounts or concentrations in uM of a chemical in different tissues as functions of time based on the dose and dosing frequency.

## Usage

```
solve_pbt(chem.name = NULL, chem.cas = NULL, times=NULL, parameters=NULL,
          days=10, tsteps = 4, daily.dose=1,dose = NULL,doses.per.day=NULL,
          initial.values=NULL,plots=F,suppress.messages=F,species="Human",
          iv.dose=F,output.units='uM',method="lsoda",rtol=1e-8,atol=1e-12,
          default.to.human=F,recalc.blood2plasma=F,recalc.clearance=F,
          dosing.matrix=NULL,adjusted.funbound.plasma=T,regression=T,
          restrictive.clearance = T,...)
```

## Arguments

chem.name	Either the chemical name, CAS number, or the parameters must be specified.
chem.cas	Either the chemical name, CAS number, or the parameters must be specified.
times	Optional time sequence for specified number of days. Dosing sequence begins at the beginning of times.
parameters	Chemical parameters from parameterize_pbt function, overrides chem.name and chem.cas.
days	Length of the simulation.
tsteps	The number time steps per hour.
daily.dose	Total daily dose, mg/kg BW.
dose	Amount of a single dose, mg/kg BW. Overwrites daily.dose.
doses.per.day	Number of doses per day.
initial.values	Vector containing the initial concentrations or amounts of the chemical in specified tissues with units corresponding to output.units. Defaults are zero.
plots	Plots all outputs if true.

<code>suppress.messages</code>	Whether or not the output message is suppressed.
<code>species</code>	Species desired (either "Rat", "Rabbit", "Dog", "Mouse", or default "Human").
<code>iv.dose</code>	Simulates a single i.v. dose if true.
<code>output.units</code>	Desired units (either "mg/L", "mg", "umol", or default "uM").
<code>method</code>	Method used by integrator (deSolve).
<code>rtol</code>	Argument passed to integrator (deSolve).
<code>atol</code>	Argument passed to integrator (deSolve).
<code>default.to.human</code>	Substitutes missing animal values with human values if true (hepatic intrinsic clearance or fraction of unbound plasma).
<code>recalc.blood2plasma</code>	Recalculates the ratio of the amount of chemical in the blood to plasma using the input parameters, calculated with hematocrit, Funbound.plasma, and Krbc2pu.
<code>recalc.clearance</code>	Recalculates the the hepatic clearance (Clmetabolism) with new million.cells.per.gliver parameter.
<code>dosing.matrix</code>	Vector of dosing times or a matrix consisting of two columns or rows named "dose" and "time" containing the time and amount, in mg/kg BW, of each dose.
<code>adjusted.Funbound.plasma</code>	Uses adjusted Funbound.plasma when set to TRUE along with partition coefficients calculated with this value.
<code>regression</code>	Whether or not to use the regressions in calculating partition coefficients.
<code>restrictive.clearance</code>	Protein binding not taken into account (set to 1) in liver clearance if FALSE.
<code>...</code>	Additional arguments passed to the integrator.

## Details

Note that the model parameters have units of hours while the model output is in days.

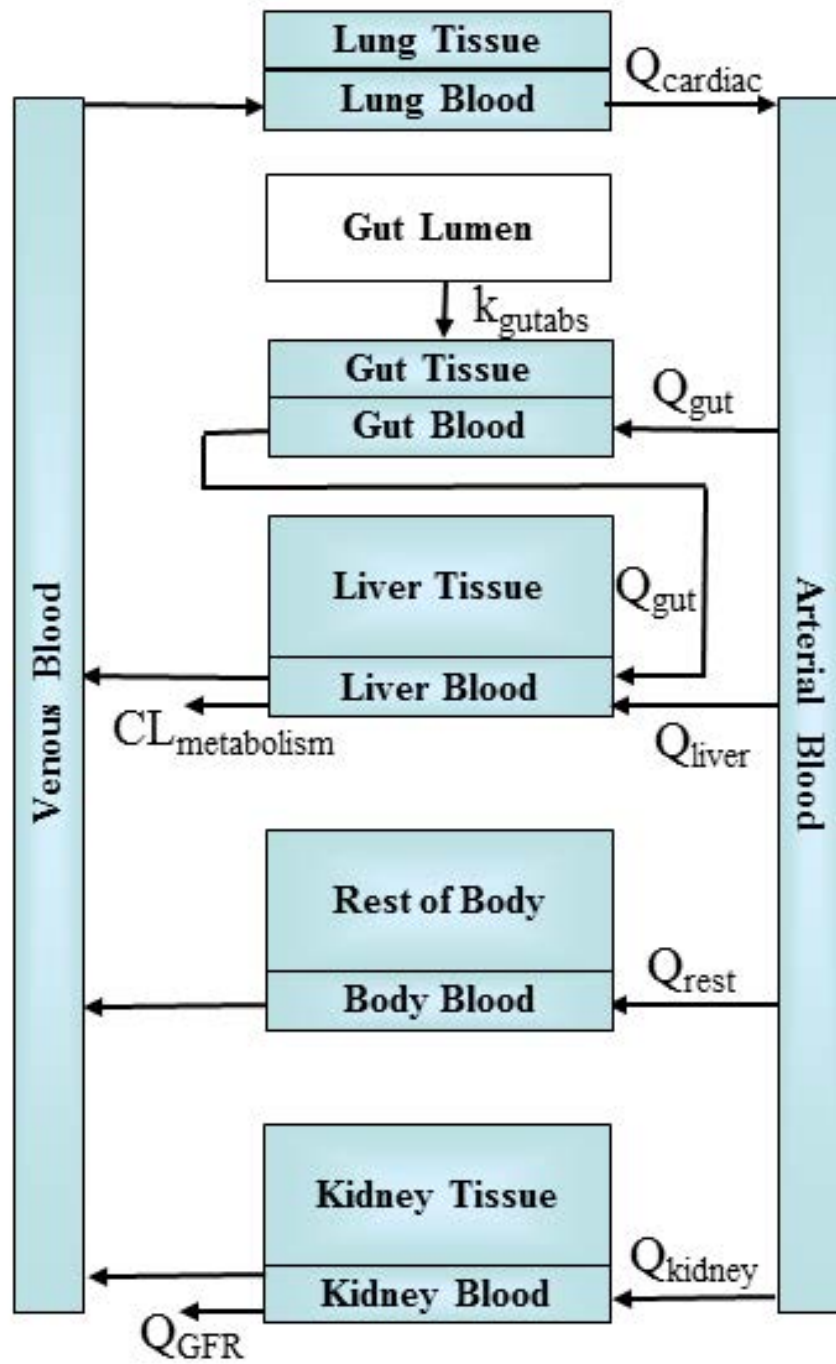
Default NULL value for `doses.per.day` solves for a single dose.

The compartments used in this model are the gutlumen, gut, liver, kidneys, veins, arteries, lungs, and the rest of the body.

The extra compartments include the amounts or concentrations metabolized by the liver and excreted by the kidneys through the tubules.

AUC is the area under the curve of the plasma concentration.

Model Figure



altalt

**Value**

A matrix of class `deSolve` with a column for time(in days), each compartment, the area under the curve, and plasma concentration and a row for each time point.

**Author(s)**

John Wambaugh and Robert Pearce

**References**

Pearce, Robert G., et al. "Httk: R package for high-throughput toxicokinetics." *Journal of statistical software* 79.4 (2017): 1.

**Examples**

```
solve_pbtok(chem.name='Bisphenol-A',dose=.5,days=1,doses.per.day=2,tsteps=2)
out <- solve_pbtok(chem.name='bisphenola',dose=0,output.units='mg',
                  plots=TRUE,initial.values=c(Agut=200))
params <- parameterize_pbtok(chem.cas="80-05-7")
solve_pbtok(parameters=params)

## Not run:
parameters <- parameterize_pbtok(chem.name = "triclosan", species = "rat")
parameters["Funbound.plasma"] <- 0.1
out <- solve_pbtok(parameters=parameters)

library("ggplot2")
out <- solve_pbtok(chem.name = "Bisphenol A", days = 50, doses.per.day = 3)
plot.data <- as.data.frame(out)
css <- calc_analytic_css(chem.name = "Bisphenol A")
c.vs.t <- ggplot(plot.data,aes(time, Cplasma)) + geom_line() +
  geom_hline(yintercept = css) + ylab("Plasma Concentration (uM)") +
  xlab("Day") + theme(axis.text = element_text(size = 16), axis.title =
  element_text(size = 16), plot.title = element_text(size = 17)) +
  ggtitle("Bisphenol A")
print(c.vs.t)

## End(Not run)
```

---

spleen\_mass\_children *Predict spleen mass for children.*

---

**Description**

For individuals under 18, predict the spleen mass from height, weight, and gender, using equations from Ogiu et al.



**Usage**

```
spleen_mass_children(height, weight, gender)
```

**Arguments**

height	Vector of heights in cm.
weight	Vector of weights in kg.
gender	Vector of genders (either 'Male' or 'Female').

**Value**

A vector of spleen masses in kg.

---

spline_heightweight	<i>Smoothing splines for log height vs. age and log body weight vs. age, along with 2-D KDE residuals, by race and gender.</i>
---------------------	--

---

**Description**

# Smoothing splines and KDE fits to joint distribution of height and weight residuals pre-calculated from NHANES height, weight, and age data by race/ethnicity and gender.

**Usage**

```
spline_heightweight
```

**Format**

A data.table with 6 variables:

g Gender: Male or Female

r Race/ethnicity: Mexican American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black, Other

height\_spline A list of smooth.spline objects, each giving a smoothed relationship between log height in cm and age in months

weight\_spline A list of smooth.spline objects, each giving a smoothed relationship between log body weight in kg and age in months

hw\_kde A list of kde objects; each is a 2-D KDE of the distribution of log height and log body weight residuals about the smoothing splines.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

spline_hematocrit	<i>Smoothing splines for log hematocrit vs. age in months, and KDE residuals, by race and gender.</i>
-------------------	---

---

**Description**

Smoothing splines and KDE residuals pre-calculated from NHANES hematocrit and age data by race/ethnicity and gender.

**Usage**

spline\_hematocrit

**Format**

A data.table with 6 variables:

gender Gender: Male or Female

reth Race/ethnicity: Mexican American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black, Other

hct\_spline A list of smooth.spline objects, each giving a smoothed relationship between log hematocrit and age in months

hct\_kde A list of kde objects; each is a KDE of the distribution of residuals about the smoothing spline.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

spline_serumcreat	<i>Smoothing splines for log serum creatinine vs. age in months, along with KDE residuals, by race and gender.</i>
-------------------	--

---

**Description**

# Smoothing splines and KDE residuals pre-calculated from NHANES serum creatinine and age data by race/ethnicity and gender.

**Usage**

spline\_serumcreat

**Format**

A data.table with 6 variables:

gender Gender: Male or Female

reth Race/ethnicity: Mexican American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black, Other

sc\_spline A list of smooth.spline objects, each giving a smoothed relationship between log serum creatinine and age in months

sc\_kde A list of kde objects; each is a KDE of the distribution of residuals about the smoothing spline.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

tc.dt

*Toxcast Data*

---

**Description**

This data set is used in Vignette 6.

**Usage**

tc.dt

---

tissue.data

*Tissue composition and species-specific physiology parameters*

---

**Description**

This data set contains values from Schmitt (2008) and Ruark et al. (2014) describing the composition of specific tissues and from Birnbaum et al. (1994) describing volumes of and blood flows to those tissues, allowing parameterization of toxicokinetic models for human, mouse, rat, dog, or rabbit. Tissue volumes were calculated by converting the fractional mass of each tissue with its density (both from ICRP), lumping the remaining tissues into the rest-of-body, excluding the mass of the gastrointestinal contents

**Usage**

tissue.data

**Format**

A data.frame containing 13 rows and 20 columns.

**Author(s)**

John Wambaugh, Robert Pearce, and Nisha Sipes

**Source**

Pearce et al. (2017), in preparation,

Wambaugh, John F., et al. "Toxicokinetic triage for environmental chemicals." *Toxicological Sciences* (2015): 228-237.

**References**

Birnbaum, L and Brown, R and Bischoff, K and Foran, J and Blancato, J and Clewell, H and Dedrick, R (1994). Physiological parameter values for PBPK model. International Life Sciences Institute, Risk Science Institute, Washington, DC

Ruark, Christopher D., et al. "Predicting passive and active tissue: plasma partition coefficients: Interindividual and interspecies variability." *Journal of pharmaceutical sciences* 103.7 (2014): 2189-2198.

Schmitt, W. (2008). General approach for the calculation of tissue to plasma partition coefficients. *Toxicology in vitro : an international journal published in association with BIBRA* 22(2), 457-67, 10.1016/j.tiv.2007.09.010.

ICRP. Report of the Task Group on Reference Man. ICRP Publication 23 1975

---

tissue_masses_flows	<i>Given a data.table describing a virtual population by the NHANES quantities, generates HHTK physiological parameters for each individual.</i>
---------------------	--

---

**Description**

Given a data.table describing a virtual population by the NHANES quantities, generates HHTK physiological parameters for each individual.

**Usage**

```
tissue_masses_flows(tmf_dt)
```

**Arguments**

tmf_dt	A data.table generated by gen_age_height_weight(), containing variables gender, reth, age_months, age_years, weight, and height.
--------	--

**Value**

The same data.table, with additional variables describing tissue masses and flows.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

tissue_scale	<i>Allometric scaling.</i>
--------------	----------------------------

---

**Description**

Allometrically scale a tissue mass or flow based on  $\text{height}^{3/4}$ .

**Usage**

```
tissue_scale(height_ref, height_indiv, tissue_mean_ref)
```

**Arguments**

height_ref	Reference height in cm.
height_indiv	Individual height in cm.
tissue_mean_ref	Reference tissue mass or flow.

**Value**

Allometrically scaled tissue mass or flow, in the same units as tissue\_mean\_ref.

**Author(s)**

Caroline Ring

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

---

well\_param

*Microtiter Plate Well Descriptions for Armitage et al. (2014) Model*

---

### Description

Microtiter Plate Well Descriptions for Armitage et al. (2014) model from Honda et al. (submitted)

### Usage

well\_param

### Format

A data frame with 53940 rows and 10 variables:

**area\_bottom**

**cell\_yield**

**diam**

**sysID**

**v\_total**

**v\_working**

**well\_desc**

**well\_number**

### Author(s)

Greg Honda

### Source

<http://www.diamondse.info/>

### References

Armitage, J. M.; Wania, F.; Arnot, J. A. Environ. Sci. Technol. 2014, 48, 9770-9779. [dx.doi.org/10.1021/es501955g](https://doi.org/10.1021/es501955g)

Honda, Gregory S., et al. "Using the Concordance of In Vitro and In Vivo Data to Evaluate Extrapolation Assumptions", submitted.

---

Wetmore.data

*Published toxicokinetic predictions based on in vitro data*

---

### Description

This data set gives the chemical specific predictions for serum concentration at steady state resulting from constant infusion exposure, as published in a series of papers from Barbara Wetmore's group at the Hamner Institutes for Life Sciences. Predictions include the median and 90% interval in uM and mg/L. Calculations were made using the 1 and 10 uM in vitro measured clearances.

### Usage

Wetmore.data

### Format

A data.frame containing 577 rows and 20 columns.

### Source

Wambaugh, John F., et al. "Toxicokinetic triage for environmental chemicals." *Toxicological Sciences* (2015): 228-237.

### References

Wetmore, B.A., Wambaugh, J.F., Ferguson, S.S., Sochaski, M.A., Rotroff, D.M., Freeman, K., Clewell, H.J., Dix, D.H., Andersen, M.E., Houck, K.A., Allen, B., Judson, R.S., Sing, R., Kavlock, R.J., Richard, A.M., and Thomas, R.S., "Integration of Dosimetry, Exposure and High-Throughput Screening Data in Chemical Toxicity Assessment," *Toxicological Sciences* 125 157-174 (2012)

Wetmore, B.A., Wambaugh, J.F., Ferguson, S.S., Li, L., Clewell, H.J. III, Judson, R.S., Freeman, K., Bao, W, Sochaski, M.A., Chu T.-M., Black, M.B., Healy, E, Allen, B., Andersen M.E., Wolfinger, R.D., and Thomas R.S., "The Relative Impact of Incorporating Pharmacokinetics on Predicting in vivo Hazard and Mode-of-Action from High-Throughput in vitro Toxicity Assays" *Toxicological Sciences*, 132:327-346 (2013).

Wetmore, B. A., Wambaugh, J. F., Allen, B., Ferguson, S. S., Sochaski, M. A., Setzer, R. W., Houck, K. A., Strobe, C. L., Cantwell, K., Judson, R. S., LeCluyse, E., Clewell, H.J. III, Thomas, R.S., and Andersen, M. E. (2015). "Incorporating High-Throughput Exposure Predictions with Dosimetry-Adjusted In Vitro Bioactivity to Inform Chemical Toxicity Testing" *Toxicological Sciences*, kfv171.

---

 Wetmore2012

*Published toxicokinetic predictions based on in vitro data from Wetmore et al. 2012.*


---

### Description

This data set overlaps with Wetmore.data and is used only in Vignette 4 for steady state concentration.

### Usage

Wetmore2012

### Format

A data.frame containing 13 rows and 15 columns.

### References

Wetmore, B.A., Wambaugh, J.F., Ferguson, S.S., Sochaski, M.A., Rotroff, D.M., Freeman, K., Clewell, H.J., Dix, D.H., Andersen, M.E., Houck, K.A., Allen, B., Judson, R.S., Sing, R., Kavlock, R.J., Richard, A.M., and Thomas, R.S., "Integration of Dosimetry, Exposure and High-Throughput Screening Data in Chemical Toxicity Assessment," *Toxicological Sciences* 125 157-174 (2012)

---

 wfl

*WHO weight-for-length charts*


---

### Description

Charts giving weight-for-length percentiles for boys and girls under age 2.

### Usage

wfl

### Format

A data.table object with variables

Sex 'Male' or 'Female'

Length length in cm

L, M, S LMS parameters; see [www.cdc.gov/growthcharts/percentile\\_data\\_files.htm](http://www.cdc.gov/growthcharts/percentile_data_files.htm)

P2.3, P5, P10, P25, P50, P75, P90, P95, **and** P97.7 weight percentiles



**Details**

For infants under age 2, weight class depends on weight for length percentile. #'

**Underweight** <2.3rd percentile

**Normal weight** 2.3rd-97.7th percentile

**Obese** >=97.7th percentile

**Author(s)**

Caroline Ring

**Source**

[http://www.cdc.gov/growthcharts/who/girls\\_weight\\_head\\_circumference.htm](http://www.cdc.gov/growthcharts/who/girls_weight_head_circumference.htm) and [http://www.cdc.gov/growthcharts/who/boys\\_weight\\_head\\_circumference.htm](http://www.cdc.gov/growthcharts/who/boys_weight_head_circumference.htm)

**References**

Ring, Caroline L., et al. "Identifying populations sensitive to environmental chemicals by simulating toxicokinetic variability." *Environment International* 106 (2017): 105-118

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