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local the,help = {},[[
brknbad: explore the world better, explore the world for good.
(c) 2022, Tim Menzies

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     | Ba    | Bad <----.  planning= (better - bad)
     |    56 |          |  monitor = (bad - better)
     .-------.------.   |
             | Be   |   v
             |    4 | Better
             .------.

USAGE:
  ./bnb [OPTIONS]

OPTIONS:
  -bins  -b   max. number of bins            = 16
  -best  -B   best set                       = .5
  -rest  -R   rest is -R*best                = 4
  -cohen -c   cohen                          = .35
  -goal  -g   goal                           = recurrence-events
  -K     -K   manage low class counts        = 1
  -M     -M   manage low evidence counts     = 2
  -seed  -S   seed                           = 10019
  -wait  -w   wait                           = 10

OPTIONS (other):
  -dump  -d   dump stack on error, then exit = false
  -file  -f   file name                      = ../etc/data/breastcancer.csv
  -help  -h   show help                      = false
  -todo  -t   start up action                = nothing
]]

local used={}
local function cli(long,key,short,x)
  assert(not used[short], "repeated short flag ["..short.."]")
  used[short]=short
  for n,flag in ipairs(arg) do
    if flag==short or flag==long then
      x = x=="false" and true or x=="true" and "false" or arg[n+1] end end
  if type(x)=="string" then
    x = x:match"^%s*(.-)%s*$"
    if     x=="true"  then x=true
    elseif x=="false" then x= false
    else   x=tonumber(x) or x end end
  the[key]=x end

help:gsub("\n ([-](([^%s]+))[%s]+(-[^%s]+)[^\n]*%s([^%s]+)",cli)
if the.help then os.exit(print(help)) end
return the

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--
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-- OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE
-- OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

local b4={}; for k,_ in pairs(_ENV) do b4[k]=k end
local R    = require
local the  = R"the"
local lib  = R"lib"
local abcd = R"abcd"
local bin, rule                 = R"bin", R"rule"
local num,sym                   = R"num", R"sym"
local ako, egs, summary         = R"ako", R"egs", R"summary"
local learn101,learn201,learn301= R"learn101", R"learn201", R"learn301"

local ish,items,o,oo,powerset = lib.ish,lib.items,lib.o,lib.oo,lib.powerset
local rnds, rnd = lib.rnds, lib.rnd
-- ## Convenctions:
-- lower case for instance methods, leading upper case for class methods (e.g.
-- start ach file witha  sime new method that lists the attributes
-- creation, management of sets of instances)

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local fails=0
local function ok(test,msg)
  print("", test and "PASS "or "FAIL ",msg or "")
  if not test then
    fails = fails+1 ; if the and the.dump then assert(test,msg) end end end

local demo={}
function demo.copy(     t,u)
  t={a={b={c=10},d={e=200}}, f=300}
  u= lib.copy(t)
  t.a.b.c= 20
  print(u.a.b.c)
  oo(t)
  oo(u)
  lib.dent(u)
  end

function demo.rnd()
  oo(rnds{23.1111111}) end

function demo.collect()
  local function aux(x,y) return x*y end
  oo(lib.collect({10,20,30},aux)) end

function demo.ent()
  local a,b = lib.ent{a=9,b=7}
  print(a,b)
  ok(ish(lib.ent{a=9,b=7}, .98886), "entropy")  end

function demo.items()
  for  x in items{10,20,30} do print(x) end
  local n=0
  print(33)
  for  x in items(the.file) do n=n+1; if n<=5 then print(100); oo(x) end end end

function demo.powerset()
  for _,x in pairs(powerset{10,20,30,40,50}) do oo(x) end end

 function demo.many( t)
  t={};for j = 1,1000 do t[#t+1] = j end
  print(900,"+", o(many(t,10,900)))
  print(1,100,o(many(t,10,1,100)))
  print(300,700, o(many(t,10,300,700))) end

function demo.new()
  dent(summary.new{"Name","Age","gender","Weight-"}) end

function demo.clone(   i,t,best,rest, x)
  i={rows={},cols=nil}
  the.file = "../etc/data/auto93.csv"
  bins=xplain(the.file)
  for _,row in pairs(i.rows) do
      x=row[col].at end end

local function qq(i,q)
  print(q[1], fmt("%15s = %-8s best= %s/%s rest= %s/%s",i.cols[q[2]].name, q[3],q[4],q[5],q[6],q[7])) end

function demo.nb1()
  local i = nb1(the.file);
  local acc, out = score(i); print(acc); map(out,function(q) qq(i,q) end) end

function demo.nb2()
  the.file = "../etc/data/diabetes.csv"
  the.goal = "positive"
  local i = nb2(the.file);
  abcd(i.log,true) end

function demo.nb2a()
  the.file = "../etc/data/diabetes.csv"
  the.goal = "positive"
  for _,bins in pairs{2,5,9} do
    print(bins)
    the.bins = bins
    local i = nb2(the.file);
    abcd(i.log,true)
    --local acc, out = score(i); print(acc)
    --map(out,function(q) q4(i,q) end)  end end
end end

function demo.bins(   t)
  local t,n = {},30
  for j=1,n do push(t, {x=j, y=j<.6*n and 1 or j<.8*n and 2 or 3}) end
  map(bins(t,20),oo)
end

function demo.nb3()
  the.file = "../etc/data/diabetes.csv"
  the.goal = "positive"
  the.bins = 16
  local i = nb3(the.file);
  abcd(i.log,true)
  local acc, out = score(i);  map(out,function(q) qq(i,q) end)
end

-------------------------------------------------------------------------------

fails = 0
local defaults=lib.copy(the)
local todos = defaults.todo == "all" and slots(demo) or {defaults.todo}
for _,todo in pairs(todos) do
  the = lib.copy(defaults)
  math.randomseed(the.seed or 10019)
  if demo[todo] then demo[todo]() end end

for k,v in pairs(_ENV) do if not b4[k] then print("??",k,type(v)) end end
os.exit(fails)

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---                    ###
---                  #  =  #             "This ain't chemistry.
---                  #######              This is art."
```

```lua
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local lib = require"lib"
local has2,has3,inc,inc2,sort = lib.has2,lib.has3,lib.inc,lib.inc2,lib.sort

local _={}
function _.new() return {
   h={}, nh=0,e={}, n=0, wait=the.wait,
   bests=0,rests=0,best={}, rest={},log=log or {}, cols={}} end

function _.classify(i,t,use)
  local hi,out = -1
  for h,val in pairs(i.h) do
    local prior = ((i.h[h] or 0) + the.K)/(i.n + the.K*i.nh)
    local l = prior
    for col,x in pairs(t) do
      if x ~= "?" and i.cols[col].indep then
        l=l*(has3(i.e,col,x,h) + the.M*prior)/((i.h[h] or 0) + the.M) end end
    if l>hi then hi,out=l,h end end
  return out end

function _.test(i,t)
  if i.n > the.wait then push(i.log,{want=t[#t], got=_.classify(i,t)}) end  end

function _.train(i,t)
  local more, kl = false, t[#t]
  for col,x in pairs(t) do
    if x ~="?" then
      more = true
      inc3(i.e, col, x, kl)
      if col ~= #t then
        inc2(kl==the.goal and i.best or i.rest, col,x) end end end
  if more then
    i.n = i.n + 1
    if not i.h[kl] then i.nh = i.nh + 1 end
    inc(i.h, kl)
    if kl==the.goal then i.bests=i.bests+1 else i.rests=i.rests+1 end end end

function _.score(i)
  local acc,out=0,{}
  for key,x in pairs(i.log) do if x.want==x.got then acc=acc+1/#i.log end end
  for col,xns in pairs(i.best) do
    for x,b in pairs(xns) do
      local r  = has2(i.rest,col,x)
      local r1 = r/i.rests
      local b1 = b/i.bests
      push(out, {100*(b1^2/(b1+r1))//1, col,x,b,i.bests,r,i.rests}) end end
  return acc, sort(out,down1) end

return function(data, log)
  local i = _.new()
  for row in items(data) do
    if   #i.cols == 0
    then i.cols = collect(row,function(j,s) return {name=s, indep=j ~= #row} end)
    else test(i,row); train(i,row) end end
  return i end
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local R=require
local the,lib, ako, nb1 = R"the",R"lib",R"ako", R"learn101"
local collect = lib.collect

return function(data,  log)
  local tmp,xnums = {}
  local function discretize(c,x,    col)
    if x ~= "?" then
      col = xnums[c]
      if col then x=(x - col.lo) // ((col.hi - col.lo+1E-32) / the.bins)  end end
    return x end

  local function xnum(c,name)
    if ako.xnum(name) then return {lo=1E32, hi=-1E32} end end

  local function train(c,x,    col)
    col = xnums[c]
    if col and x ~= "?" then
       col.hi = math.max(x, col.hi)
       col.lo = math.min(x, col.lo) end
    return x end

  for row in items(data) do
    push(tmp, row)
    if   xnums then collect(row, train)
    else xnums = collect(row,xnum)  end end
  for j=2,#tmp do tmp[j] = collect(tmp[j], discretize) end
  return nb1(tmp) end
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local R=require
local nb1,bin,lib  = R"learn101", R"bin", R"lib"
local collect,push = lib.collect,lib.push

return function(data,  log)
  local tmp, xnums = {}
  local function discretize(c,x,   col)
    if x ~= "?" then
      col = xnums[c]
      if col then
        for _,one in pairs(col.bins) do
          if one.lo <= x and x < one.hi then return one.id end end end end
    return x end

  local function xnum(c,name)
    if ako.xnum(name) then return {name=name, xys={},bins={}} end end

  local function train(c,x,row)
    if xnums[c] and x ~= "?" then push(xnums[c].xys, {x=x,y= row[#row]}) end end

  for row in items(data) do
    push(tmp,row)
    if   xnums then collect(row, function(c,x) return train(c,x,row) end)
    else xnums = collect(row,xnum) end end
  for where,col in pairs(xnums) do
    col.bins = bin.Xys(col.xys,where); print(col.name,#col.bins) end
  for j=2,#tmp do tmp[j] = collect(tmp[j], discretize) end
  return nb1(tmp) end

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local the=require"the"
local lib=require"lib"
local fmt,per,push,sort = lib.fmt, lib.per, lib.push, lib.sort

local _={}
function _.new(id,at,name,lo,hi,n,div)
  return {id=id,at=at,name=name,lo=lo,hi=hi,n=n,div=div} end

function _.show(i,negative)
  local x,lo,hi,big, s = i.name, i.lo, i.hi, math.huge
  if negative then
    if     lo== hi  then s=fmt("%s != %s",x,lo)
    elseif hi== big then s=fmt("%s <  %s",x,lo)
    elseif lo==-big then s=fmt("%s >= %s",x,hi)
    else                 s=fmt("%s < %s and %s >= %s",x,lo,x,hi) end
  else
    if     lo== hi  then s=fmt("%s == %s",x,lo)
    elseif hi== big then s=fmt("%s >= %s",x,lo)
    elseif lo==-big then s=fmt("%s <  %s",x,hi)
    else                 s=fmt("%s <= %s < %s",lo,x,hi) end end
  return s end

function _.select(i,row)
  local x, lo, hi = row[i.at], i.lo, i.hi
  return x=="?" or lo == hi and lo == x or lo <= x and x < hi end

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function _.Merges(bins)
  local j,n,new = 0,length(bins),{}
  while j <= n do
    j=j+1
    a=bins[j]
    if j < n then
      b = bins[j+1]
      if a.hi == b.lo then
        a.hi  = b.hi
        a.div = (a.div*a.n + b.div*b.n)/(a.n+b.n)
        a.n   = a.n + b.n
        j     = j + 1 end end
    push(new,a) end
  return #new < #bins and _.Merges(new) or bins end

local argmin
function _.Xys(xys,at,name)
  xys                 = sort(xys, upx)
  local triviallySmall = the.cohen*(per(xys,.9).x - per(xys, .1).x)/2.56
  local enoughItems    = #xys / the.bins
  local out            = {}
  argmin(1,#xys, xys, triviallySmall, enoughItems, -math.huge, at.name, out)
  out[#out].hi =  math.huge
  return out end

function argmin(lo, hi, xys, triviallySmall, enoughItems, b4, at, name,out)
  local function add(f,z) f[z] = (f[z] or 0) + 1 end
  local function sub(f,z) f[z] =  f[z] - 1       end
  local lhs, rhs, cut, div, xpect, xy = {},{}
  for j=lo,hi do add(rhs, xys[j].y) end
  div = ent(rhs)
  if hi-lo+1 > 2*enoughItems then
    for j=lo,hi - enoughItems do
      add(lhs, xys[j].y)
      sub(rhs, xys[j].y)
      local n1,n2 = j - lo +1, hi-j
      if   n1         > enoughItems and
           n2         > enoughItems and
           xys[j].x ~= xys[j+1].x and  -- there is a break here
           xys[j].x  - xys[lo].x > triviallySmall and
           xys[hi].x - xys[j].x  > triviallySmall
      then xpect = (n1*ent(lhs) + n2*ent(rhs)) / (n1+n2)
           if xpect < div then  -- cutting here simplifies things
             cut, div = j, xpect end end end
  end -- end if
  if   cut
  then b4 = argmin(lo,   cut, xys,triviallySmall,enoughItems,b4,at,name,out)
       b4 = argmin(cut+1,hi , xys,triviallySmall,enoughItems,b4,at,name,out)
  else -- if no cut then the original div was never updates and is still correct
       b4 = push(out,  _.new(#out+1,at,name,b4,xys[hi].x, hi-lo+1,div)).hi end
  return b4 end

return _
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local lib=require"lib"
local bin=require"bin"
local map,push,sort = lib.map, lib.push, lib.sort

local _={}
function _.new(bins,   t)
  t = {}
  for key,one in pairs(bins) do t[one.at]=t[one.at] or {}; push(t[one.at],one) end
  return {bins=t} end

function _.selects(i,row)
  local function ors(bins)
    for key,x in pairs(bins) do if bin.select(x,row) then return true end end
    return false end
  for at,bins in pairs(i.bins) do if not ors(bins) then return false end end
  return true end

function _.show(i,bins)
  local cat, order, ors
  cat =  function(t,sep) return table.concat(t,sep) end
  order= function(a,b)  return a.lo < b.lo end
  ors=   function(bins)
          return cat(map(bin.Merges(sort(bins,order)),bin.show)," or ") end
  return cat(map(i.bins, ors)," and ") end

return _
```

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local _={}

_.num    = function(x) return x:find"^[A–Z]" end
_.goal   = function(x) return x:find"[–+!]"  end
_.klass  = function(x) return x:find"!$"     end
_.ignore = function(x) return x:find":$"     end
_.weight = function(x) return x:find"–$" and -1 or 1 end
_.xnum   = function(x) return _.num(x) and not _.goal(x) end

return _
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local ako = require"ako"

local _ = {}
function _.new(at,name)
  return {at=at or 0, name=name or "",
          nump=true, indep=false, n=0, w = ako.weight(name or ""),
          lo=math.huge, hi=-math.huge, mu=0, m2=0, sd=0, bins={}} end

function _.add(i,x,   d)
  if x ~= "?" then
    i.n = i.n+1
    i.lo = math.min(x, i.lo)
    i.hi = math.max(x, i.hi)
    d      = x - i.mu
    i.mu = i.mu + d/i.n
    i.m2 = i.m2 + d*(x - i.mu)
    i.sd = ((i.m2<0 or i.n<2) and 0) or ((i.m2/(i.n - 1))^0.5) end
 return x end

return _
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local _ = {}

function _.new(at,name)
  return {at=at or 0, name=name or "",
          nump=false, indep=false, n=0,
          has={}, most=0, mode=nil} end

function _.add(i,x)
  if x ~= "?" then
    i.n = i.n + 1
    i.has[x] = 1 + (i.has[x] or 0)
    if i.has[x] > i.most then
      i.mode,i.most = x,i.has[x] end end
   return x end

return _
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local R=require
local ako,lib,sym,num = R"ako",R"lib",R"sym",R"num"
local norm,push = lib.norm, lib.push

local _ = {}
function _.new(names)
  return _.init({names=names, klass=nil,xy= {}, x= {}, y={}},names) end

function _.init(i, names)
  for at,name in pairs(names) do
    local now = (ako.num(name) and num.new or sym.new)(at,name)
    push(i.xy, now)
    if not ako.ignore(name)  then
      if not ako.goal(name)  then now.indep = true end
      if     ako.klass(name) then i.klass=now      end
      push(now.indep and i.x or i.y, now)          end end
  return i end

function _.add(i,row)
  for _,col in pairs(i.xy) do
    (col.nump and num or sym).add(col, row[col.at]) end
  return row end

function _.better(i,row1,row2)
  local s1, s2, n, e = 0, 0, #i.y, math.exp(1)
  for _,col in pairs(i.y) do
    local a  = norm(col.lo, col.hi, row1[col.at] )
    local b  = norm(col.lo, col.hi, row2[col.at] )
    s1 = s1 - e^(col.w * (a - b) / n)
    s2 = s2 - e^(col.w * (b - a) / n) end
  return s1 / n < s2 / n  end

return _
---      ___   __ _   ___
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local summary = require"summary"
local lib     = require"lib"
local map,sort,many = lib.map,lib.sort,lib.many
local items,slice   = lib.items,lib.slice

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local _={}
function _.new() return {rows={}, cols={}} end

function _.Init(data,    i)
  i= _.new()
  for row in items(data) do
    if  #i.cols==0 then i.cols=summary.new(row) else
      push(i.rows, summary.add(i.cols,row)) end end
  return i end

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function _.mid(i,cols)
   local function mid(col) return col.nump and col.mu or col.mode end
   return map(cols or i.cols.y, mid) end

function _.div(i,cols)
   local function div(col) return col.nump and col.sd or ent(col.has) end
   return map(cols or i.cols.y, div) end

function _.clone(old,rows)
  local i={rows={}, cols=summary.new(old.cols.names)}
  for key,row in pairs(rows or {}) do summary.add(i.cols,row) end
  return i end

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function _.dist(i,row1,row2)
  local function sym(c,x,y) return x==y and 0 or 1 end
  local function num(c,x,y)
    if     x=="?" then y = norm(c.lo, c.hi, y); x=y<.5 and 1 or 0
    elseif y=="?" then x = norm(c.lo, c.hi, x); y=x<.5 and 1 or 0
    else              x,y = norm(c.lo, c.hi, x), norm(c.lo, c.hi, y) end
    return math.abs(x-y) end
  local function dist(c,x,y)
    return x=="?" and y=="?" and 1 or (c.nump and num or sym)(c,x,y) end
  local d, n = 0, #i.cols.x
  for key,c in pairs(i.cols.x) do d= d + dist(c, row1[c.at], row2[c.at])^the.e e
nd
  return (d/n)^(1/the.e) end


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function _.bestRest(i)
  i.rows  = sort(i.rows, function(a,b) return summary.better(i.cols,a,b) end)
  local n = (#i.rows)^the.best
  return slice(i.rows, 1,          n),      -- top n things
         many( i.rows, n*the.rest, n+1) end -- some sample of the rest

function _.Contrasts(i, rows1, rows2)
  local function contrast(col)
    local function asBin(x,ys,     n,div)
      n,div = ent(ys)
      return bin.new(id, col.at, col.name, x, x, n, div) end
    local symbols, xys, x = {},{}
    for klass,rows in pairs{rows1,rows2} do
      for key,row in pairs(rows) do
        x = row[col.at]
        if x ~= "?" then
          if not col.nump then inc2(symbols,x,klass) end
          push(xys, {x=x, y=klass}) end end end
    return col.nump and bins(xys, col.at) or collect(symbols, asBin) end
  local out, tmp = {}
  for key,col in pairs(i.cols.x) do
    tmp = contrast(col)
    if #tmp > 1 then
      for key,one in pairs(tmp) do push(out, one) end end end
   return out end

function _.xplain(i)
  best, rest = _.bestRest(i)
  return _.contrasts(i, best,rest) end

return _
```

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local lib=require"lib"

local _={}

function _.new(data,rx)
  return {data= data or "data",rx= rx or "rx",
          known={},a={},b={},c={},d={},yes=0,no=0} end

function _.exists(i,x,   new)
  new = not i.known[x]
  lib.inc(i.known,x)
  if new then
    i.a[x]=i.yes + i.no; i.b[x]=0; i.c[x]=0; i.d[x]=0 end end

function _.report(i,    p,out,a,b,c,d,pd,pf,pn,f,acc,g,prec)
  p = function (z) return math.floor(100*z + 0.5) end
  out= {}
  for x,xx in pairs( i.known ) do
    pd,pf,pn,prec,g,f,acc = 0,0,0,0,0,0,0
    a= (i.a[x] or 0); b= (i.b[x] or 0); c= (i.c[x] or 0); d= (i.d[x] or 0);
    if b+d > 0     then pd   = d     / (b+d)        end
    if a+c > 0     then pf   = c     / (a+c)        end
    if a+c > 0     then pn   = (b+d) / (a+c)        end
    if c+d > 0     then prec = d     / (c+d)        end
    if 1-pf+pd > 0 then g=2*(1-pf) * pd / (1-pf+pd) end
    if prec+pd > 0 then f=2*prec*pd / (prec + pd)   end
    if i.yes + i.no > 0 then
       acc= i.yes / (i.yes + i.no) end
    out[x] = {data=i.data,rx=i.rx,num=i.yes+i.no,a=a,b=b,c=c,d=d,acc=p(acc),
              prec=p(prec), pd=p(pd), pf=p(pf),f=p(f), g=p(g), class=x} end
  return out end

function _.pretty(t)
  print""
  local s1  = "%10s | %10s | %4s | %4s | %4s | %4s "
  local s2  = "| %3s | %3s| %3s | %4s | %3s | %3s |"
  local d,s = "---", (s1 .. s2)
  print(fmt(s,"db","rx","a","b","c","d","acc","pd","pf","prec","f","g"))
  print(fmt(s,d,d,d,d,d,d,d,d,d,d,d,d))
  for key,x in pairs(lib.slots(t)) do
    local u = t[x]
    print(lib.fmt(s.." %s", u.data,u.rx,u.a, u.b, u.c, u.d,
                               u.acc, u.pd, u.pf, u.prec, u.f, u.g, x)) end end

function _.adds(gotwants, show,data, rx)
  local i = _.is(data,rx)
  for key,one in pairs(gotwants) do
    _.exists(i,one.want)
    _.exists(i,one.got)
    if one.want == one.got then i.yes=i.yes+1 else i.no=i.no+1 end
    for x,xx in pairs(i.known) do
      if   one.want == x
      then lib.inc(one.want == one.got and i.d or i.b, x)
      else lib.inc(one.got  == x       and i.c or i.a, x) end end end
  return show and _.pretty(_.report(i)) or _.report(i) end

return _.adds
```

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local _={}

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function _.per(t,p) return t[ (p or .5)*#t//1 ] end

function _.ent(t)
  local n=0; for _,m in pairs(t) do n = n+m end
  local e=0; for _,m in pairs(t) do if m>0 then e= e+m/n*math.log(m/n,2) end end
  return -e,n end

function _.norm(lo,hi,x) return math.abs(hi-lo)<1E-9 and 0 or (x-lo)/(hi-lo) end

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function _.ish(x,y,z) return math.abs(x-y) <= (z or 0.001) end

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function _.inc(f,a,n)      f=f or{};f[a]=(f[a] or 0) + (n or 1)     return f end
function _.inc2(f,a,b,n)   f=f or{};f[a]=_.inc(f[a]  or {},b,n); return f end
function _.inc3(f,a,b,c,n) f=f or{};f[a]=_.inc2(f[a] or{},b,c,n);return f end

function _.has(f,a)      return f[a]                        or 0 end
function _.has2(f,a,b)   return f[a] and _.has( f[a],b)   or 0 end
function _.has3(f,a,b,c) return f[a] and _.has2(f[a],b,c) or 0 end

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_.unpack = table.unpack

function _.push(t,x) t[1 + #t] = x; return x end

function _.powerset(s)
  local function aux(s)
    local t = {{}}
    for i = 1, #s do
      for j = 1, #t do
        t[#t+1] = {s[i], _.unpack(t[j])} end end
    return t end
  return _.sort(aux(s), function(a,b) return #a < #b end) end

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function _.map(t, f, u)
  u={}; for k,v in pairs(t) do u[1+#u]=f(v) end; return u end
function _.collect(t,f,u)
  u={}; for k,v in pairs(t) do u[k]=f(k,v) end; return u end
function _.copy(t,    u)
  if type(t) ~= "table" then return t end
  u={}; for k,v in pairs(t) do u[_.copy(k)] = _.copy(v) end; return u end

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function _.sort(t,f) table.sort(t,f); return t end

function _.upx(a,b)   return a.x < b.x end
function _.up1(a,b)   return a[1] < b[1] end
function _.down1(a,b) return a[1] > b[1] end

function _.slots(t, u)
  local function public(k) return tostring(k):sub(1,1) ~= "_" end
  u={};for k,v in pairs(t) do if public(k) then u[1+#u]=k end end
  return _.sort(u) end

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function _.any(a,lo,hi)
  lo,hi = lo or 1, hi or #a; return a[ (lo+(hi-lo)*math.random())//1 ] end

function _.many(a,n,lo,hi,  u)
  u={}; for j=1,n do _.push(u, _.any(a,lo,hi)) end; return u end

function _.slice(a,lo,hi,    u)
  u,lo,hi = {},lo or 1,hi or #a; for j=lo,hi do u[1+#u]=a[j] end; return u end
```

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function _.words(s,sep,   t)
  sep="([^" .. (sep or ",")  .. "]+)"
  t={}; for y in s:gmatch(sep) do t[1+#t] = y end; return t end

function _.things(s) return _.map(_.words(s), thing) end

function _.thing(x)
  x = x:match"^%s*(.-)%s*$"
  if x=="true" then return true elseif x=="false" then return false end
  return tonumber(x) or x end

function _.items(src,f)
  local function file()
    src,f = io.input(src),f or _.things
    return function() x=io.read()
             print(6000,f)
             if x then return f(x) else io.close(src) end end end
  local function tbl(   x)
    print(300)
    x,f = 0, f or function(z) return z end
    return function() if x< #src then x=x+1; return f(src[x]) end end end
  if src then
    return type(src) == "string" and file() or tbl() end end

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_.fmt = string.format

function _.oo(t) print(_.o(t)) end

function _.o(t,  seen, u)
  if type(t)~="table" then return tostring(t) end
  seen = seen or {}
  if seen[t] then return "..." end
  seen[t] = t
  local function show1(x) return _.o(x, seen) end
  local function show2(k) return _.fmt(":%s %s",k, _.o(t[k],seen)) end
  u = #t>0 and _.map(t,show1) or _.map(_.slots(t),show2)
  return (t._is or "")..."{"..table.concat(u," ")..."}" end

function _.dent(t,  seen,pre)
  pre,seen = pre or "", seen or {}
  if seen[t] then t= "..." end
  if type(t)~="table" then return print(pre .. tostring(t)) end
  seen[t]=t
  for _,k in pairs(_.slots(t)) do
    local v = t[k]
    local after = type(v)=="table" and "\n" or "\t"
    io.write(pre,":",k,after)
    if   type(v)=="table"
    then _.dent(v,seen,"| "..pre)
    else print(v) end end end

function _.rnds(t,f)
  return _.map(t, function(x) return _.rnd(x,f) end) end

function _.rnd(x,f)
  return _.fmt(type(x)=="number" and (x~=x//1 and f or "%5.2f") or "%s",x) end

return _
```