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Assignment 1:
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Part 1: Queries

1. Frugal doctors

– a relation that lists all brand-name drug products' DIN and its price
$NamedDrugs(namedDIN, namedprice) := \Pi_{DIN,price}(Price \bowtie Product)$

– a relation that lists all generic drug products' DIN, its price, and its corresponding brand-name drug DIN.
$GenericDrugs(genericDIN, genericprice, parentDIN) := \Pi_{DIN,price,brand}(Price \bowtie Generic)$

– a relation that lists all brand-name drug DIN that has at least 1 generic product (Note: if only a brand-drug has a generic alternative, a doctor that prescribed the brand-name drug won't be selected whether or not this brand-name drug is more expensive that its generic alternatives)
$$ExpensiveNamed(DIN) := \Pi_{namedDIN}\left[\sigma_{parentDIN=namedDIN}(NamedDrugs \times GenericDrugs)\right]$$

– a relation that lists all generic drugs' DINs that have at least 1 other alternative generic product with the same corresponding brand-named product that has a lower price.
$$ExpensiveGeneric(DIN) := \Pi_{G1.genericDIN}\left(\sigma_{\substack{G1.genericDIN \neq G2.genericDIN \\ \wedge \\ G1.parentDIN = G2.parentDIN \\ \wedge \\ G1.genericprice > G2.genericprice}}\left[(\rho_{G1}GenericDrugs) \times (\rho_{G2}GenericDrugs)\right]\right)$$

– a relation that contains DIN of all drugs that are NOT the cheapest option of its kind, which includes:
a) brand-name drugs that have at least on genertic alterative (no matter if the genertic alternative is higher priced or not);
b) generic drugs that have other genertic alternatives of the same brand-name drug with lower price.
$ExpensiveDrugs(DIN) := ExpensiveNamed \cup ExpensiveGeneric$

– a relation that contains doctors that have prescribed at least one drug that either prescribed a brand-name drug that has generic alternatives or some generic drugs that have lower-priced generic alternatives with the same brand-name (i.e. doctors that shouldn't be in the final answer).

$$RichDoctors(doctor) := \Pi_{doctor}\left[\sigma_{drug=DIN}(ExpensiveDrugs \times Prescription)\right]$$

– a relation that contains doctors who have prescribed 2 or more drugs (since only doctors that have prescribed at least two different drugs want to be considered)
$TwoDrugDoctor(doctor) :=$

$$\Pi_{D1.doctor}\left(\sigma_{\substack{D1.doctor=D2.doctor \\ \wedge \\ D1.RxID \neq D2.RxID \\ \wedge \\ D1.drug \neq D2.drug}}\left[(\rho_{D1}Prescription) \times (\rho_{D2}Prescription)\right]\right)$$

– a relation that contains only frugal doctors.

$$FrugalDoctor(doctor) := \Pi_{doctor}(TwoDrugDoctors - RichDoctors)$$

2. Price gougers

– relation contains only the RxID of prescriptions of generic drugs
$$GenericPre(RxID) := \Pi_{RxID}\left[\sigma_{drug=DIN}(Generic \times Prescription)\right]$$

– find OCP of all pharmacists that filled at least 1 generic drug
$$GenericPharm(OCP) := \Pi_{pharmacist}(GenericPre \bowtie Filled)$$

– find all pharmacists that have never filled a generic drug excluding ones that have never filled anything
$$NoGenericPharm(OCP) := \left[\Pi_{OCP}(\rho_{F(RxID,date,OCP)}Filled)\right] - GenericPharm$$

– report OCP, name and date of registration
$$PriceGougers(OCP, name, registered) := \Pi_{OCP,name,registered}(Pharmacist \bowtie NoGenericPharm)$$

3. Potential doctor shopping

– all prescriptions of brand-named drug products
$BrandPrescription(RxID, OHIP, DIN, doctor) :=$

$$\Pi_{RxID,patient,DIN,doctor}\left[\sigma_{DIN=drug}(Prescription \times Product)\right]$$

– all prescriptions of generic drug products
$GenericPrescription(RxID, OHIP, DIN, doctor, brand) :=$

$$\Pi_{RxID,patient,DIN,doctor,brand}\left[\sigma_{DIN=drug}(Prescription \times Generic)\right]$$

– all patient who have been prescribed the same DIN by 2 different doctors

$$SameDIN(OHIP) := \Pi_{P1.patient}\left(\sigma_{\substack{P1.RxID \neq P2.RxID \\ \wedge \\ P1.doctor \neq P2.doctor \\ \wedge \\ P1.drug = P2.drug \\ \wedge \\ P1.patient = P2.patient}}\left[(\rho_{P1}Prescription) \times (\rho_{P2}Prescription)\right]\right)$$

–all patient who have been prescribed 1 brand-named and 1 of its generic by 2 different doctors

$$BrandandGeneric(OHIP) :=$$

$$\Pi_{B.OHIP}\left(\sigma_{\substack{B.RxID \neq G.RxID \\ \wedge \\ B.doctor \neq G.doctor \\ \wedge \\ B.DIN \neq G.DIN \\ \wedge \\ B.OHIP = G.OHIP \\ \wedge \\ B.DIN = G.brand}}\left[(\rho_{B}BrandPrescription) \times (\rho_{G}GenericPrescription)\right]\right)$$

–all patient who have been prescribed 2 different generic products that have the same brand name equivalent

$$GenericandGeneric(OHIP) :=$$

$$\Pi_{G1.OHIP}\left(\sigma_{\substack{G1.RxID \neq G2.RxID \\ \wedge \\ G1.doctor \neq G2.doctor \\ \wedge \\ G1.DIN \neq G2.DIN \\ \wedge \\ G1.OHIP = G2.OHIP \\ \wedge \\ G1.brand = G2.brand}}\left[(\rho_{G1}GenericPrescription) \times (\rho_{G2}GenericPrescription)\right]\right)$$

–Union all 3 different classes of patient for final result, and report all attributes by product with relation Patient

$$PotentialDoctorShopping(OHIP, name, phone) :=$$

$$\Pi_{OHIP,name,phone}\left[(SameDIN \cup BrandandGeneric \cup GenericandGeneric) \bowtie Patient\right]$$

4. Safest ingredient

   Cannot be expressed.

5. Drug shortage

– A relation of all drugs and its manufacturer

$$Drugs(DIN, manufacturer) := (\Pi_{DIN,manufacturer}Product) \cup (\Pi_{DIN,manufacturer}Generic)$$

– all unfilled prescriptions

$$unfilledPre(RxID, patient, DIN) :=$$

$$\left[(\Pi_{RxID}Prescription) - (\Pi_{RxID}Filled)\right] \bowtie (\Pi_{RxID,patient,drug}Prescription)$$

– find all drug's DIN that has more than 2 unfilled prescriptions and at least 2 different patients

$unfilledDrugs(DIN) :=$

$$\Pi_{U1.DIN}\left(\sigma_{\substack{U1.patient\neq U2.patient \\ \wedge \\ U1.RxID\neq U2.RxID \\ \wedge \\ U3.RxID\neq U2.RxID \\ \wedge \\ U1.RxID\neq U3.RxID \\ \wedge \\ U1.DIN=U2.DIN \\ \wedge \\ U3.DIN=U2.DIN}}\left[(\rho_{U1}unfilledPre)\times(\rho_{U2}unfilledPre)\times(\rho_{U3}unfilledPre)\right]\right)$$

– using the DIN, report DIN and manufacturer

$DrugShortage(DIN, manufacturer) := Drugs \bowtie unfilledDrugs$

6. Protecting drug patents

– find all pairs of brand-named drugs, where the first drug DIN is strictly less than the second drug's DIN (i.e. no pseudo-duplicate pairs)

$AllPairs(DIN1, name1, DIN2, name2) :=$

$$\Pi_{P1.DIN,P1.name,P2.DIN,P2.name}\left(\sigma_{P1.DIN<P2.DIN}\left[(\rho_{P1}Product)\times(\rho_{P2}Product)\right]\right)$$

– Intermediate table with every possible brand-named DIN paired with every possible active ingredient in brand-named drugs

$Intermediate(DIN, name, ingredient) := (\Pi_{DIN,name}Product) \times (\Pi_{ingredient}Contains)$

– find what each brand-named DIN lacks in ingredient, ie. every tuple indicates drug with DIN does NOT contain ingredient

$NotContain(DIN, name, ingredient) :=$

$$Intermediate - \left[(\Pi_{DIN,name}Product) \bowtie (\Pi_{DIN,ingredient}Contains)\right]$$

– new Contains table with names of the brand-names drugs

$BrandContains(DIN, name, ingredient) := (\Pi_{DIN,name}Product) \bowtie (\Pi_{DIN,ingredient}Contains)$

– find out all pairs of brand-named drugs that at least differs by 1 ingredient ,i.e. if a brand-name contains an ingredient that the other brand-name drug doesn't have, then this pair of brand-name drug is certainly no the pair of drugs with exactly the same ingredients

$DifferentDrugs(DIN1, name1, DIN2, name2) :=$

$$\Pi_{C.DIN,C.name,N.DIN,N.name}\left(\sigma_{\substack{C.DIN\neq N.DIN \\ \wedge \\ C.ingredient=N.ingredient}}\left[(\rho_{C}BrandContains)\times(\rho_{N}NotContains)\right]\right)$$

– find out all pairs of brand-named drugs that have the exact same ingredient

$ProtecDrugParent(DIN1, name1, DIN2, name2) := AllPairs - DifferentDrugs$

7. Recent narcotics

– find all brand-name narcotic
$BrandNar(DIN, drugname) := \Pi_{DIN,name}\sigma_{schedule='narcotic'}Product$

– find all generic narcotic
$GenericNar(DIN, drugname) :=$

$$\Pi_{Generic.DIN,Generic.name}\left[\sigma_{\substack{schedule='narcotic' \\ \wedge \\ Product.DIN=Generic.brand}}(Product \times Generic)\right]$$

– all narcotic drugs, including brand-name and generic
$Nar(DIN, drugname) := BrandNar \cup GenericNar$

– all filled Prescription with DIN information included
$FilledPre(RxID, fdate, OCP, DIN) :=$

$$\Pi_{RxID,fdate,pharmacist,drug}\left[(\rho_{F(RxID,fdate,pharmacist)}Filled) \bowtie Prescription\right]$$

– all filled prescription with a narcotic
$FilledNar(RxID, fdate, OCP, DIN, drugname) :=$

$$\Pi_{RxID,fdate,OCP,DIN,drugname}FilledPre \bowtie Nar$$

– find the relation of all prescriptions with Narcotic that were not the most recent filled ones
$EarlyNar(RxID, fdate, OCP, DIN, drugname) :=$

$$\Pi_{\substack{E1.RxID \\ E1.fdate \\ E1.OCP \\ E1.DIN \\ E1.drugname}}\left(\sigma_{\substack{E1.RxID \neq E2.RxID \\ \wedge \\ E1.fdate < E2.fdate \\ \wedge \\ E1.OCP = E2.OCP}}\left[(\rho_{E1}FilledNar) \times (\rho_{E2}FilledNar)\right]\right)$$

– find OCP, drugname, filled date information for the more recent filled narcotic prescription
$PartialInfo(OCP, drugname, fdate) :=$

$$\Pi_{OCP,drugname,fdate}(FilledNar - EarlyNar)$$

– find full pharmacists and drug information for the most recent filled narcotic prescription
$RecentNarcotics(OCP, name, drugname, fdate) :=$

$$\Pi_{OCP,name,drugname,fdate}PartialInfo \bowtie Pharmacist$$

8. Patients at risk

– find all instances where 2 or more drugs has been prescribed on the same day to the same patient by the same doctor
$TwoDrug(DIN1, DIN2, doctor, date) :=$

$$\Pi_{P1.drug,P2.drug,P1.doctor,P1.date}\left(\sigma_{\substack{P1.drug\neq P2.drug \\ \wedge \\ P1.doctor=P2.doctor \\ \wedge \\ P1.patient=P2.patient \\ \wedge \\ P1.date=P2.date}}\left[(\rho_{P1}Prescription)\times(\rho_{P2}Prescription)\right]\right)$$

– get all interact-able ingredient for every brand named drug
$Interactablebrand(DIN1, reactant) :=$
$\Pi_{DIN,ingredient2}\left[Contains \bowtie (\rho_{I(ingredient,ingredient2)}Interaction)\right]$

– get all interact-able ingredient for every generic drug
$Interactiblegeneric(DIN1, reactant) :=$
$\Pi_{DIN,ingredient2}\left[Generic \bowtie (\rho_{C(brand,ingredient1,strength,unit)}Contains) \bowtie Interaction\right]$

– get all interact-able ingredient for every drug, including generic and brand-named drugs
$Interactable(DIN1, reactant) := Interactablebrand \cup Interactiblegeneric$

– relation that contains all possible combination of drug1 DIN and its possible interactive ingredient
$TwoDrug1(DIN1, reactant, DIN2, doctor, date) := Interactable \bowtie TwoDrug$

– relation that contain all active ingredient for both generic and brand-named drugs
$AllDrugs(DIN2, ingredient) :=$

$$\left(\Pi_{DIN,ingredient}\left[Generic \bowtie (\rho_{(brand,ingredient,strength,unit)}Contains)\right]\right)\cup(\Pi_{DIN,ingredient}Contains)$$

– relation contains all the information from previous, and also the ingredient in drug2.
$TwoDrugFinal(DIN1, reactant, DIN2, ingredient2, doctor, date) :=$
$\Pi_{DIN1,reactant,DIN2,ingredient,doctor,date}(TwoDrug1 \bowtie AllDrugs)$

– report all by comparing reactant (from drug1) to ingredient (from drug 2)
$PatientAtRisk(doctor, date) := \Pi_{doctor,date}\sigma_{reactant=ingredient}TwoDrugFinal$

9. Many generics

Cannot be expressed.

10. Long-time customers

– find all OCP and name of all the most senior pharmacists.
$Seniors(sOCP) :=$

$$\Pi_{OCP} Pharmacist - \Pi_{P1.OCP}\left(\sigma_{\substack{P1.OCP \neq P2.OCP \\ \wedge \\ P1.registered > P2.registered}}\left[(\rho_{P1} Pharmacist) \times (\rho_{P2} Pharmacist)\right]\right)$$

– find all OCP and name of all the most junior pharmacists.
$Juniors(jOCP) :=$

$$\Pi_{OCP} Pharmacist - \Pi_{P1.OCP}\left(\sigma_{\substack{P1.OCP \neq P2.OCP \\ \wedge \\ P1.registered < P2.registered}}\left[(\rho_{P1} Pharmacist) \times (\rho_{P2} Pharmacist)\right]\right)$$

– find intermediate table that contains date of filled prescription, OHIP, patient name, and pharmacist's OCP.
$Intermediate(date, OHIP, name, OCP) :=$

$$\Pi_{date,patient,name,OCP}\left[(\rho_{P(RxID,pdate,patient,drug,doctor,dosage,note)} Prescription) \bowtie Filled \bowtie (\rho_{Pat(patient,name,dob,phone,address)} Patient)\right]$$

– find relation that contains all the dates where a patient had a prescription filled by a senior.
$SeniorFilled(OHIP, name, sdate) := \Pi_{OHIP,name,date}\left[\sigma_{sOCP=OCP}(Intermediate \times Seniors)\right]$

– find relation that contains all the dates where a patient had a prescription filled by a junior.
$JuniorFilled(OHIP, name, jdate) := \Pi_{OHIP,name,date}\left[\sigma_{jOCP=OCP}(Intermediate \times Juniors)\right]$

– find relation that only contains the earliest date where a patient had a prescription filled by a senior.
$EarliestSenior(OHIP, name, sdate) :=$

$$SeniorFilled - \Pi_{P1.OHIP,P1.name,P1.sdate}\left[\sigma_{\substack{P1.sdate > P2.sdate \\ \wedge \\ P1.OHIP = P2.OHIP}}\left[(\rho_{P1} SeniorFilled) \times (\rho_{P2} SeniorFilled)\right]\right]$$

– find relation that only contains the earliest date where a patient had a prescription filled by a junior.
$EarliestJunior(OHIP, name, jdate) :=$

$$JuniorFilled - \Pi_{P1.OHIP,P1.name,P1.jdate}\left[\sigma_{\substack{P1.jdate > P2.jdate \\ \wedge \\ P1.OHIP = P2.OHIP}}\left[(\rho_{P1} JuniorFilled) \times (\rho_{P2} JuniorFilled)\right]\right]$$

– report all information.
$LongTimeCustomer(OHIP, name, jdate, sdate) :=$
$\Pi_{OHIP,name,jdate,sdate}(EarliestSenior \bowtie EarliestJunior)$

11. Lots of competition

– find all manufacturers who make at least 1 brand-name drugs.
$BrandManu(manufacturer, bDIN) := \Pi_{manufacturer,DIN} Product$

– make an intermediate table that describes for every brand-name drug every manufacturer makes, it also makes an equivalent generic drug.
$Intermediate(manufacturer, bDIN, gmanu) :=$

$$\Pi_{B1.manufacturer.B1.bDIN,B2.manufacturer}\left(\sigma_{B1.manufacturer=B2.manufacturer}[(\rho_{B1}BrandManu)\times (\rho_{B2}BrandManu)]\right)$$

– relation that list all the brand-name product, its manufacturer, and all the manufacturer that makes the generic form of the brand-name product
$BrandAndGeneric(manufacture, bDIN, gmanu) :=$

$$\Pi_{manufacturer,bDIN,gmanu}\left[BrandManu \bowtie \rho_{G(DIN,bDIN,name,gmanu)}Generic\right]$$

– find all manufacturer that did NOT make a generic product for each of its brand-named product.
$BadManu(manufacturer, bDIN) := \Pi_{manufacturer,bDIN}(Intermediate - BrandAndGeneric)$

– all manufacturer that make a generic product for every of its brand-named product, in other words, satisfy the first 2 rule in the question
$GoodBrandManu(manufacturer, bDIN) := BrandManu - BadManu$

– all manufacturer and its brand-named product that satisfy rule 1 and 2, and at least 1 different manufacturer makes a generic product of the brand-named drug
$BrandAndDiffGeneric(manufacture, bDIN) :=$

$$\Pi_{manufacturer,bDIN}\left(\sigma_{manufacturer\neq bmanu}\left[GoodBrandManu \bowtie (\rho_{G(DIN,bDIN,name,bmanu)}Generic)\right]\right)$$

– isolate out the manufacturers that at least one of its brand-named product does not have a different manufacturer that makes a generic equivalent.
$Monopolies(manufacturer) := \Pi_{manufacturer}(GoodBrandManu - BrandAndDiffGeneric)$

– Finally find all manufactures that satisfy all 3 rules in the question
$LotsCompetition(manufacturer) := (\Pi_{manufacturer} GoodBrandManu) - Monopolies$

Part 2: Additional Integrity Constraints

1. Symmetry

   $$Interaction - Interaction \bowtie (\rho_{I(ingredient2,ingredient1)} Interaction) = \emptyset$$

2. Don't surpass those with seniority
   Cannot be expressed.

3. Brand-name first

   – find all prescriptions of brand-named drugs
   $BrandPre(bRxID, bdate, bDIN, bdoctor) :=$

   $$\Pi_{RxID,date,drug,doctor}\left(Prescription \bowtie \left[\Pi_{drug}\left(\rho_{P(drug,name,manufacturer,form,schedule,route)} Product\right)\right]\right)$$

   – find all prescriptions of generic drugs
   $GenericPre(gRxID, gdate, gDIN, parentDIN, gdoctor) :=$

   $$\Pi_{RxID,date,drug,brand,doctor}\left(Prescription \bowtie \left[\Pi_{drug,brand}\left(\rho_{G(drug,brand,name,manufacturer)} Generic\right)\right]\right)$$

   – of all the prescriptions of generic drugs, only have the earliest prescription of generic drugs that have the same brand-name equivalent by the same doctor. If brand-named drug A has 2 generic drug B and C, and doctor X prescribed B before C, then table will only have Prescription for B for doctor X.
   $EarliestGenericWithSameBrand(gRxID, gdate, gDIN, parentDIN, gdoctor) :=$

   $$GenericPre - \left[\Pi_{\substack{G1.gRxID,\\ G1.gdate,\\ G1.gDIN,\\ G1.parentDIN,\\ G1.gdoctor}}\left(\sigma_{\substack{G1.gdate>G2.gdate \\ \wedge \\ G1.gdoctor=G2.gdoctor \\ \wedge \\ G1.parentDIN=G2.parentDIN}}(\rho_{G1} GenericPre \times \rho_{G2} GenericPre)\right)\right]$$

   – find all earliest prescription of each brand-named drug by the same doctor. If doctor A prescribed the same brand-named drug multiple times, only the first time will be recorded, if doctor A prescribed several brand-name drugs, each drug's earliest prescription will be recorded, if doctor A only prescribed a brand-name drug once, this record will be stored
   $EarliestBrandPre(bRxID, bdate, bDIN, bdoctor) :=$

   $$BrandPre - \left[\Pi_{\substack{B1.RxID,\\ B1.bdate,\\ B1.bDIN,\\ B1.bdoctor}}\left(\sigma_{\substack{B1.bdoctor=B2.bdoctor \\ \wedge \\ B1.bDIN=B2.bDIN \\ \wedge \\ B1.bdate>B2.bdate}}(\rho_{B1} BrandPre \times \rho_{B2} BrandPre)\right)\right]$$

– find all the times when the same doctor prescribed a brand-named drug after prescribing an equivalent generic drug.
$GenericFirst(DIN, gdoctor) :=$

$$\Pi_{gDIN,gdoctor}\left[\sigma_{\substack{gdoctor=bdoctor \\ \wedge \\ gdate \leq bdate \\ \wedge \\ bDIN=parentDIN}}\left(EarliestBrandPre \times EarliestGenericWithSameBrand\right)\right]$$

– find all the times when the same doctor prescribed a generic drug but never prescribed its equivalent brand-named drug
$OnlyGeneric(DIN, gdoctor) := (\Pi_{parentDIN,gdoctor} EarliestGenericWithSameBrand) -$
$\left[\Pi_{parentDIN,gdoctor}\left(\rho_{E(bRxID,bdate,parentDIN,gdoctor)} EarliestBrandPre\right)\right]$

– Integrity Constraint
$GenericFirst \cup OnlyGeneric = \emptyset$

4. Don't over-prescribe narcotics

– Find all detailed prescriptions of brand-named narcotics.
$DetailedPre(drug, RxID, date, patient, doctor) :=$

$$\Pi_{\substack{drug, \\ RxID, \\ date, \\ patient, \\ doctor}}\left[\sigma_{schedule='narcotic'}\left(Prescription \bowtie (\rho_{(drug,name,manufacturer,form,schedule,route)} Product)\right)\right]$$

– Integrity Constraint

$$\sigma_{\substack{D1.drug=D2.drug \\ \wedge \\ D1.date=D2.date \\ \wedge \\ D1.doctor=D2.doctor \\ \wedge \\ D1.patient=D2.patient \\ \wedge \\ D1.RxID \neq D2.RxID}}\left[(\rho_{D1} DetailedPre) \times (\rho_{D2} DetailedPre)\right] = \emptyset$$