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Part 1: Queries

1. Frugal doctors

– Brand-name drugs that do not have a generic form and have a recorded price.

$$BrandItemOnly(DIN) :=$$
$$\Pi_{Product.DIN}\sigma_{Product.DIN=Price.DIN}(Product \times Price) -$$
$$\Pi_{Product.DIN}\sigma_{\substack{Product.DIN=Price.DIN \\ \wedge \\ Price.DIN=Generic.brand}}(Product \times Price \times Generic)$$

– Brand-name drugs (with price) that do have a generic alternative.

$$HasGeneric(DIN) := \Pi_{Product.DIN}(Product \bowtie Price) - \Pi_{DIN}(BrandItemOnly)$$

– Cheapest generic versions (ties allowed) among generics sharing the same brand.

$$CheapestGenericDrugs(DIN) :=$$
$$\Pi_{DIN}\Big(\Pi_{DIN,price}(Generic \bowtie Price) - \Pi_{g1.DIN,g1.price}\sigma_{\substack{g1.DIN \neq g2.DIN \\ \wedge \\ g1.price > g2.price \\ \wedge \\ g1.brand = g2.brand}}\big((\rho_{g1}(Generic \bowtie Price)) \times (\rho_{g2}(Generic \bowtie Price))\big)\Big)$$

– Non-cheapest generic drugs.

$$NonCheapestDrugs(DIN) := \Pi_{DIN}(Generic \bowtie Price) - CheapestGenericDrugs$$

– Prescriptions for drugs that have a recorded price (attach the Price row).

$$PricedRx(RxID, date, patient, drug, doctor, dosage, note, DIN, price) :=$$
$$Prescription \bowtie_{Prescription.drug=Price.DIN} Price$$

– Doctors who have prescribed one or more priced drugs.

$$OneOrMoreDrugs(doctor) := \Pi_{doctor}(PricedRx)$$

– Doctors who have prescribed two or more different priced drugs.

$$TwoOrMoreDrugs(doctor) := \Pi_{p1.doctor}\Big(\sigma_{\substack{p1.doctor=p2.doctor \\ \wedge \\ p1.drug \neq p2.drug}}\big(\rho_{p1}(PricedRx) \times \rho_{p2}(PricedRx)\big)\Big)$$

– Doctors who have only prescribed one priced drug.

$$OnlyOneDrug(doctor) := \Pi_{doctor}(OneOrMoreDrugs) - \Pi_{doctor}(TwoOrMoreDrugs)$$

– Doctors who have made at least one priced prescription.

$$SomePricedDoctors(doctor) := \Pi_{doctor}(PricedRx)$$

– Doctors who prescribed at least one invalid priced drug: (i) a brand drug that has a generic alternative, OR (ii) a generic drug that is not the cheapest among its brand-equivalents.

$InvalidDoctors(doctor) :=$

$\Pi_{doctor}\sigma_{PricedRx.drug=HasGeneric.DIN}(PricedRx \times HasGeneric)$

$\cup\, \Pi_{doctor}\sigma_{PricedRx.drug=NonCheapestDrugs.DIN}(PricedRx \times NonCheapestDrugs)$

– Final answer: priced-prescription doctors excluding those who only prescribed one priced drug and those who ever prescribed an invalid priced drug.

$Answer(doctor) := SomePricedDoctors - (OnlyOneDrug \cup InvalidDoctors)$

2. Potential doctor shopping

– Two generics with the same brand-name equivalent.

$$GenericPairs(DIN1, DIN2) := \Pi_{G1.DIN,G2.DIN}\sigma_{G1.brand=G2.brand \overset{\wedge}{} G1.DIN \neq G2.DIN}\big(\rho_{G1}(Generic) \times \rho_{G2}(Generic)\big)$$

– A brand-name drug and its generic equivalent (both directions).

$BrandGenericPairs(DIN1, DIN2) :=$

$$\rho_{DIN1,DIN2}\Big(\Pi_{brand,DIN}\, Generic\Big) \cup \rho_{DIN1,DIN2}\Big(\Pi_{DIN,brand}\, Generic\Big)$$

– Identity pairs where every drug is equivalent to itself.

$IdentityPairs(DIN1, DIN2) :=$

$$\rho_{DIN1,DIN2}\Big(\Pi_{P1.DIN,P2.DIN}\sigma_{P1.DIN=P2.DIN}\big(\rho_{P1}(Product) \times \rho_{P2}(Product)\big)\Big) \cup$$

$$\rho_{DIN1,DIN2}\Big(\Pi_{G1.DIN,G2.DIN}\sigma_{G1.DIN=G2.DIN}\big(\rho_{G1}(Generic) \times \rho_{G2}(Generic)\big)\Big)$$

– All pairs of equivalent medications.

$EquivalentPairs(DIN1, DIN2) := GenericPairs \cup BrandGenericPairs \cup IdentityPairs$

– Patients prescribed equivalent medications by two different doctors.

$DoctorShopping(patient) :=$

$$\Pi_{P1.patient}\sigma_{P1.patient=P2.patient \overset{\wedge}{} P1.doctor \neq P2.doctor}\big((\rho_{P1}(Prescription) \bowtie_{P1.drug=DIN1} EquivalentPairs)$$

$$\bowtie_{DIN2=P2.drug} \rho_{P2}(Prescription)\big)$$

– OHIP number, name, and phone number of patients who doctor shop.

$Answer(OHIP, name, phone) := \Pi_{OHIP,name,phone}(DoctorShopping \bowtie_{patient=OHIP} Patient)$

3. Safest ingredient

– cannot be expressed

4. Drug shortage

– All unfilled prescriptions (RxID of prescriptions not in Filled).
$UnfilledRxIDs(RxID) := \Pi_{RxID} Prescription - \Pi_{RxID} Filled$

– Unfilled prescriptions with drug and patient information.
$UnfilledPrescriptions(RxID, drug, patient) := \Pi_{RxID,drug,patient}(UnfilledRxIDs \bowtie Prescription)$

– Drugs with at least two different patients having unfilled prescriptions.
$TwoPatients(drug) :=$

$$\Pi_{U1.drug}\sigma_{\substack{U1.drug=U2.drug \\ \wedge \\ U1.patient\neq U2.patient}}\big(\rho_{U1}(UnfilledPrescriptions)\times\rho_{U2}(UnfilledPrescriptions)\big)$$

– Drugs with more than two unfilled prescriptions.
$MoreThanTwo(drug) :=$

$$\Pi_{U1.drug}\sigma_{\substack{U1.drug=U2.drug \\ \wedge \\ U1.drug=U3.drug \\ \wedge \\ U1.RxID\neq U2.RxID \\ \wedge \\ U1.RxID\neq U3.RxID \\ \wedge \\ U2.RxID\neq U3.RxID}}\big(\rho_{U1}(UnfilledPrescriptions) \times \rho_{U2}(UnfilledPrescriptions) \times \rho_{U3}(UnfilledPrescriptions)\big)$$

– Drugs meeting both conditions.
$ShortDrugs(drug) := TwoPatients \cap MoreThanTwo$

– DIN and manufacturer for brand-name drugs in shortage.
$BrandShortage(DIN, manufacturer) := \Pi_{DIN,manufacturer}(ShortDrugs \bowtie_{drug=DIN} Product)$

– DIN and manufacturer for generic drugs in shortage.
$GenericShortage(DIN, manufacturer) := \Pi_{DIN,manufacturer}(ShortDrugs \bowtie_{drug=DIN} Generic)$

– DIN and manufacturer of all drugs in shortage.
$Answer(DIN, manufacturer) := BrandShortage \cup GenericShortage$

5. Protecting drug patents

– Ignore strength and unit: keep only the ingredient set per drug.
$Ing(DIN, ingredient) := \Pi_{DIN,ingredient}(Contains)$

– All pairs of different brand-name drugs (no pseudo-duplicates), with names.
$AllNamedPairs(DIN1, Name1, DIN2, Name2) :=$
$\Pi_{P1.DIN,P1.name,P2.DIN,P2.name}\sigma_{P1.DIN<P2.DIN}\big(\rho_{P1}(Product) \times \rho_{P2}(Product)\big)$

– Ingredient triples for the first drug in each pair.
$AllPairs(DIN1, ingredient1, DIN2, ingredient2) :=$

$$\Pi_{B1.DIN,B1.ingredient,B2.DIN,B2.ingredient}\sigma_{B1.DIN<B2.DIN}\big(\rho_{B1}(Ing)\times\rho_{B2}(Ing)\big)$$

– For each drug pair, list ingredients of the first drug (DIN1 side).

$$PairIng1(DIN1, DIN2, ingredient) :=$$

$$\Pi_{DIN1,DIN2,ingredient}\sigma_{AllNamedPairs.DIN1=I1.DIN}\big(AllNamedPairs\times\rho_{I1}(Ing)\big)$$

– For each drug pair, list ingredients of the second drug (DIN2 side).

$$PairIng2(DIN1, DIN2, ingredient) :=$$

$$\Pi_{DIN1,DIN2,ingredient}\sigma_{AllNamedPairs.DIN2=I2.DIN}\big(AllNamedPairs\times\rho_{I2}(Ing)\big)$$

– Ingredients of drug1 that are missing from drug2 (for the same pair).

$$Missing12(DIN1, DIN2, ingredient) :=$$

$$PairIng1 - \Pi_{DIN1,DIN2,ingredient}\sigma_{\substack{PairIng1.DIN1=PairIng2.DIN1\\ \wedge\ PairIng1.DIN2=PairIng2.DIN2\\ \wedge\ PairIng1.ingredient=PairIng2.ingredient}}(PairIng1\times PairIng2)$$

– Ingredients of drug2 that are missing from drug1 (for the same pair).

$$Missing21(DIN1, DIN2, ingredient) :=$$

$$PairIng2 - \Pi_{DIN1,DIN2,ingredient}\sigma_{\substack{PairIng1.DIN1=PairIng2.DIN1\\ \wedge\ PairIng1.DIN2=PairIng2.DIN2\\ \wedge\ PairIng1.ingredient=PairIng2.ingredient}}(PairIng1\times PairIng2)$$

– Pairs of drugs that do NOT have identical ingredient sets.

$$NonMatching(DIN1, DIN2) :=$$

$$\Pi_{DIN1,DIN2}(Missing12)\cup\Pi_{DIN1,DIN2}(Missing21)$$

– Pairs of drugs that DO have identical ingredient sets.

$$MatchingDIN(DIN1, DIN2) :=$$

$$\Pi_{DIN1,DIN2}(AllNamedPairs) - NonMatching$$

– Final Answer: keep only those named pairs whose DINs are in MatchingDIN.

$$Answer(DIN1, Name1, DIN2, Name2) :=$$

$$\Pi_{DIN1,Name1,DIN2,Name2}\sigma_{\substack{AllNamedPairs.DIN1=MatchingDIN.DIN1\\ \wedge\ AllNamedPairs.DIN2=MatchingDIN.DIN2}}(AllNamedPairs\times MatchingDIN)$$

6. Patients at risk

– Active ingredients in each drug (both brand-name and generic).

$$DrugIngredients(DIN, ingredient) :=$$

$$\Pi_{DIN,ingredient}\,Contains$$

$$\cup$$

$$\Pi_{G.DIN,C.ingredient}\big(\rho_G(Generic)\bowtie_{G.brand=C.DIN}\rho_C(Contains)\big)$$

– Pairs of drugs that interact (at least one ingredient interacts).
$InteractingDrugs(DIN1, DIN2) :=$

$$\Pi_{D1.DIN, D2.DIN}\sigma_{\substack{D1.DIN \neq D2.DIN \\ \wedge \\ D1.ingredient = I.ingredient1 \\ \wedge \\ D2.ingredient = I.ingredient2}}\big(\rho_{D1}(DrugIngredients) \times \rho_{D2}(DrugIngredients) \times \rho_I(Interaction)\big)$$

– Prescriptions with same patient, doctor, and date but different drugs.
$SameDayPairs(doctor, date, drug1, drug2) :=$

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

– Doctors who prescribed interacting drugs on the same day.
$Answer(doctor, date) := \Pi_{doctor, date}\sigma_{\substack{drug1 = DIN1 \\ \wedge \\ drug2 = DIN2}}\big(SameDayPairs \times InteractingDrugs\big)$

7. Many generics
   – cannot be expressed
8. Lots of competition

– Manufacturers that make at least one brand-name drug.
$BrandManufacturers(manufacturer) := \Pi_{manufacturer} Product$

– All (manufacturer, brand DIN) pairs for brands made by that manufacturer.
$ManufacturerBrands(manufacturer, brand) := \Pi_{manufacturer, DIN} Product$

– (manufacturer, brand DIN) where manufacturer makes a generic of that brand.
$HasSelfGeneric(manufacturer, brand) :=$

$$\Pi_{P.manufacturer, G.brand}\sigma_{P.manufacturer = G.manufacturer}\big(\rho_P(Product) \bowtie_{P.DIN = G.brand} \rho_G(Generic)\big)$$

– (manufacturer, brand DIN) where manufacturer does NOT make a generic.
$MissingSelfGeneric(manufacturer, brand) :=$

$$\rho_{manufacturer, brand}(ManufacturerBrands) - HasSelfGeneric$$

– Manufacturers that fail condition 2 (at least one brand lacks self-generic).
$FailCondition2(manufacturer) := \Pi_{manufacturer} MissingSelfGeneric$

– Brand-name drugs that have a generic from another company.
$HasOtherGeneric(brand) :=$

$$\Pi_{G.brand}\sigma_{P.manufacturer \neq G.manufacturer}\big(\rho_P(Product) \bowtie_{P.DIN = G.brand} \rho_G(Generic)\big)$$

– (manufacturer, brand DIN) pairs where brand has an outside generic.

$BrandWithOther(manufacturer, brand) :=$

$$\Pi_{manufacturer,brand}\big(\rho_{manufacturer,brand}(ManufacturerBrands) \bowtie_{brand=brand} HasOtherGeneric\big)$$

– (manufacturer, brand DIN) where brand lacks an outside generic.

$MissingOtherGeneric(manufacturer, brand) := \rho_{manufacturer,brand}(ManufacturerBrands) - BrandWithOther$

– Manufacturers that fail condition 3 (at least one brand lacks outside generic).

$FailCondition3(manufacturer) := \Pi_{manufacturer} MissingOtherGeneric$

– Manufacturers meeting all three conditions.

$Answer(manufacturer) := BrandManufacturers - FailCondition2 - FailCondition3$

Part 2: Additional Integrity Constraints

1. Symmetry

   – Interaction pairs with ingredients swapped.

   $Swapped(ingredient1, ingredient2) := \Pi_{ingredient2,ingredient1}(Interaction)$

   – Enforce symmetry: every interaction must appear in both directions.

   $Answer := Interaction - Swapped = \emptyset$

2. Don't surpass those with seniority

   – cannot be expressed

3. Brand-name first

   – All prescriptions for generic drugs combined with their brand-name equivalents.

   $GenericMatchedBrand(RxID, date, patient, drug, doctor, dosage, note, DIN, brand, name, manufacturer) := \sigma_{Prescription.drug=Generic.DIN}(Prescription \times Generic)$

   – Generic prescriptions for which the same doctor prescribed the brand equivalent earlier.

   $ValidGenericPrescription(RxID, date, patient, drug, doctor, dosage, note) :=$

   $$\Pi_{\substack{GMB.RxID \\ GMB.date \\ GMB.patient \\ GMB.drug \\ GMB.doctor \\ GMB.dosage \\ GMB.note}} \sigma_{\substack{GMB.brand=P.drug \\ \wedge \\ GMB.date>P.date \\ \wedge \\ GMB.doctor=P.doctor}} \big(\rho_{GMB}(GenericMatchedBrand) \times \rho_P(Prescription)\big)$$

   – All generic prescriptions projected to the same schema.

   $AllGenericCore(RxID, date, patient, drug, doctor, dosage, note) :=$

$$\Pi_{RxID,date,patient,drug,doctor,dosage,note}(GenericMatchedBrand)$$

– Integrity constraint: every generic prescription must be valid.
$Answer := AllGenericCore - ValidGenericPrescription = \emptyset$