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ESSAY

How to think with models and targets: Hepatitis C elimination as a numbering performance

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Abstract

The field of public health is replete with mathematical models and numerical targets. In the case of disease eliminations, modelled projections and targets play a key role in evidencing elimination futures and in shaping actions in relation to these. Drawing on ideas within science and technology studies, we take hepatitis C elimination as a case for reflecting on how to think with mathematical models and numerical targets as 'performative actors' in evidence-making. We focus specifically on the emergence of 'treatment-as-prevention' as a means to trace the social and material effects that models and targets make, including beyond science. We also focus on how enumerations are made locally in their methods and events of production. We trace the work that models and targets do in relation to three analytical themes: *governing*; *affecting*; and *enacting*. This allows us to situate models and targets as technologies of governance in the constitution of health, which affect and are affected by their material relations, including in relation to matters-of-concern which extend beyond calculus. By emphasising models and targets as enactments, we draw attention to how these devices give life to new enumerated entities, which detach from their calculative origins and take flight in new ways. We make this analysis for two reasons: first, as a call to bring the social and enumeration sciences closer together to speculate on how we might think with models and targets *differently* and more *carefully*; and second, to encourage an approach to science which treats evidencing-making interventions, such as models and targets, as *performative* and *political*.

Keywords

Mathematical models; targets; enumeration; treatment-as-prevention; hepatitis C; evidence-making; performativity.

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Introduction

Numbers smack of precision. Numbers communicate a sense of control. Numbers speak a common language which transcends contexts. This is the magic often said to be afforded by numbers.

But we can think of numbers and numbering practices in multiple ways. For instance, we can think of enumerations as entities which are materialised differently according to their means, methods and events of production. There are multiple ideas condensed into this last sentence: enumerations as *entities*; enumerations as *materialised*; and enumerations as *situated*, that is, as things which are open to different eventuation according to their localised knowledge-making. This kind of thinking orientates towards what numbers *do*, what they *become*, and the effects they *make*, through their implementations, for instance, as predictions, targets, and metrics in intervention and policy. More specifically, this kind of thinking appreciates how numbers are afforded *agency* through their entanglements in practices. We can therefore appreciate enumerations as situated *interventions* (Rhodes and Lancaster, 2019a). Accordingly, we propose thinking of enumerations, and here mathematical models and numerical targets, as *performative actors* with *governing potential* in the constitution of health.

Treating numbers as performative means that they are never 'just numbers'. They become *lively*, and *do more*. In a performativity approach, numbers are not simply 'out there', and crucially, they do not pre-exist their enumerating. This means that they are not as stable or as singular as they appear, and they cannot be assumed to represent an anterior reality. Rather, numbers are *made* in the materials of science and other practices, and furthermore, they *make* effects, including beyond calculus, in the 'real worlds' of action, intervention and policy. Whereas there is a mainstream tendency to theorise action as an exclusively human capacity (done in the work of those producing, implementing and using enumerations), we are theorising action as an effect of *relations* which also entangle nonhuman actors

(Latour, 1987; Law, 2014), including the work that is done in and through enumerations (Verran, 2005; Callon and Law, 2005).

The performativity of enumerations

So, how do models, targets and other forms of enumeration perform? Drawing on ideas within science and technologies studies, we foreground our analysis by accentuating two performative effects of numbering. First, models and targets emerge in social and material relations, and tacitly embed as well as reproduce these through their assumptions and calculations. Global models of energy forecasting, for instance, can reproduce the normative assumptions of their architects, thereby orientating projections as well as shaping policies in particular directions (Wynne, 1984; Aykut, 2019). Likewise, climate change forecasts illustrate how models build their projections, with policy consequences, according to the normative and calculative assumptions underpinning them, especially in relation to how they theorise mechanisms of climate change (Jasanoff, 2010). What goes into models, shapes what comes out, in a series of recursive moves. From the outset then, we can treat models and targets as entangled effects of the *assemblages* of actors and practices which *materialise* them. Importantly, such assemblages extend beyond science, and the laboratories producing models locally, to incorporate social (and global) relations, incorporating institutions, systems, technologies, discourses, and worldviews (Law, 2012; Mccann and Ward, 2012; Aykut 2019).

Second, models and targets materially equip as well as shape actions *in the present* in light of the futures they project (Callon, 1998; Mackenzie, 2006; Michael, 2000). This means that models and targets do not merely represent, but *make*, realities. We can draw here on the foundational work of Michel Callon and others which traces how modelled economic projections *shape the markets* in which they are entangled (Callon and Numiesa, 2005; Callon, 2007; Mackenzie, 2006). This work accentuates models as performative devices in the materialisation of practices. The model *itself* becomes an 'engine' of reality-making as it travels into different actor networks and is taken up and put-to-use as a tool of projection, prediction and planning (Mackenzie, 2006). In this orientation, model outputs – what comes out – shape the material-discursive contexts of future action and policy-making, delimiting what becomes conceivable and possible. While oriented to possibility, models tend to *close-down* otherwise open and undetermined futures into actionable and plausible trajectories which are situated in relation to the particularities of the material present (Michael, 2000; Aykut, 2019). Thus, in a performativity approach to enumeration, there is a twin emphasis on the relationality of calculations and the constitutive effects of these entities.

This analysis

We contribute to this special focus of papers on mathematical modelling as social scientists. Our interest is not to debate the veracity of modelling methods or the findings produced by models. Our concern is less epistemological than *ontological*. We are interested in how the calculation devices of models and targets bring certain enumerations into being with certain social and material effects. Concentrating on mathematical models and numerical targets as they relate to the elimination of viral infection, and specifically hepatitis C and the invention of 'treatment-as-prevention', we consider what models and targets *do*; that is, how they are *put-to-use* and how they are *made-to-matter* as situated matters-of-concern (including beyond science). In what has become a 'race to eliminate' hepatitis C among other viruses, we wish step back for a moment to ask two questions: 'what realities and effects do the enumerations of models and targets make?'; and 'how are enumerations made locally in the materials, methods and events which produce them?'.

Why ask these questions? Models and targets have become ubiquitous in fields of policy and risk governance, including in relation to financial and economic markets, climate change, environment, energy, water, food, and 'natural' and humanitarian disaster (Wynne, 1984; Callon, 1998; Mackenzie, 2006; Jasanoff, 2010; Landström et al., 2011; Aykut et al., 2019; Haines, 2019). The fields of global health and evidence-based health care are also replete with models and targets (Gunning-Schepers and Van Herten, 2000; Bauer, 2013). This is clearly apparent in global efforts to eradicate disease (WHO, 2015a,b, 2016a,b, 2017). The projected and targeted elimination of HIV and hepatitis C as public health threats are prime examples (WHO, 2016b,c; UNAIDS, 2014). Without projection, futures cannot be anticipated. Models and targets are forms of "anticipatory knowledge", which "turn the future into an object of scientific enquiry and political intervention", affording an "anticipatory governance" (Guston, 2014; Ayut et al., 2019: 2). Not only do models and targets delimit futures affecting the present, this is often a *goal* of models which seek to engage directly with policy and medical interventions. We can see this in the field of hepatitis C, where mathematical models and numerical targets entangle in a viral elimination assemblage which incorporates pharmaceuticals and policy proposals among its actors. Modelled projections and numerical targets *intervene*, governing the future-present in particular ways.

We therefore take hepatitis C elimination as our case for reflecting on how to think with models and targets as performative actors in evidence-making and intervention. We invite modellers, disease elimination scientists, and policy-makers to think with us. We want to bring the social and enumeration sciences into dialogue to speculate on how we might think with models and targets

differently, and more *carefully*. This is an *ontopolitical* move, for if models and targets contribute to performing the worlds of health and viral elimination in particular ways, it is also possible to perform these worlds differently (Mol, 1999, 2002; Law, 2012). Specifically, we make three proposals. First, to think with models and targets as objects that are afforded agency as *technologies of governance* in the constitution of health and populations (governing). Second, to think with models and targets as affording *life and effects which extend beyond their original calculative spaces* (affecting). Third, to think with models and targets as devices which constitute *new enumerated entities* (enacting). Of course, these modes of governing, affecting and enacting are inseparable (as each entangle relationally). But each help us to instantiate how enumerations are *materialised* in practices (of science, intervention and policy) while at the same time *materialise* these.

Models and targets in viral elimination

Before we make our case for thinking with models and targets as modes of governing, affecting and enacting, we need to say a few words to situate a context for hepatitis C and its elimination. A now common narrative is to characterise the field of hepatitis C treatment as a site of rapid and dramatic technological change generating great promise. Pharmaceutical treatments for chronic hepatitis C – Direct-Acting Antivirals (DAAs) – promise near 100% cure of hepatitis C infection with near zero side-effects (Dore and Feld, 2015; Falade-Nwulia et al., 2017). DAAs have moved from pharmaceutical development to clinical trial to implementation at an unprecedented pace. Their implementation, which began around 2014, marked a rupture from previous Interferon-based treatments characterised by poor cure rates and debilitating side-effects. DAAs perform a 'new era' of treatment optimism, characterised as 'ground-breaking' and 'revolutionary' potential (Banerjee and Reddy, 2016; Gane, 2014; Grebely et al., 2017; Dore and Feld, 2015; Innes et al., 2015).

Models and targets materialise hepatitis C treatment promise in the DAA era. Not only are DAAs enacted to afford the promise of cure among infected individuals, they potentiate a future without hepatitis C at the level of populations, territories, and nation states (Rhodes and Lancaster, 2019b). This population-level impact is evidence-made through mathematical models of theoretical projection (Hickman et al., 2015; Pitcher et al., 2018), in which the prevention potential of hepatitis C treatment curative outcomes is projected at a scale sufficient to reduce the pool of infections, and thus transmissions, in the population at risk, including accounting for rates of re-infection among those treated (Martin, Vickerman and Hickman, 2011). The publication of models theorising hepatitis C cure as having *treatment-as-prevention* effects is a foundational moment in evidence-making (Zeller et al., 2010; Martin et al., 2011; Martin, Vickerman and Hickman, 2011). These models followed a wave of

excitement in the projection (Cohen, 2011; Cohen et al., 2011), and subsequent empirical evidencing via trials (Cohen et al., 2016), of treatment-as-prevention in the field of HIV, also heralded as 'game-changing'. Models of treatment-as-prevention continue to drive the field of hepatitis C intervention and policy, including in light of higher treatment cure rates resulting from pharmaceutical trials, and as part of wider assemblages of viral elimination promise (Martin et al., 2013; Hagan et al., 2013; Hellard et al., 2014; Innes et al., 2015; Razavi et al., 2017; Fraser et al., 2018; Ward et al., 2018; Scott et al., 2018; Zelenov et al., 2018; Kwon et al., 2019). Many of these models have also projected the intervention coverage required to meet prevention targets, including the additive effects of combining pharmaceutical treatments with other forms of prevention (Martin et al., 2013). There are also models of the cost-effectiveness of treatment-as-prevention investments (Martin et al., 2012, 2016; Scott et al., 2017, 2020; Cipriano and Goldhaber-Fiebert, 2018). In potentiating treatment-as-prevention and imagined futures in which hepatitis C is controlled, models "tantalise":

> The advent of new hepatitis C virus treatments (DDAs) […] has ushered in an era of *excitement* about the *possibility* of eliminating HCV transmission. *Tantalising* theoretical mathematical models predicting *dramatic* reductions in HCV chronic prevalence and incidence, with scale-up of HCV treatment for those at risk of transmission, have fuelled this *optimism*. (Martin, Vickerman and Hickman, 2017: 5; emphasis added).

A second foundational moment in the transformation of hepatitis C cure is the enactment of treatment-as-prevention as *viral elimination*. Critical here, has been the invention of global viral elimination targets. In 2016, the World Health Organization (WHO) released its Global Health Sector Strategy on Viral Hepatitis. Embedded within an agenda of the United Nations to control, eliminate and eradicate preventable infectious diseases including malaria, HIV and tuberculosis (United Nations, 2015), this Strategy set a goal to "eliminate viral hepatitis as a major public health threat by 2030", and accordingly, set targets to achieve this globally (WHO, 2016b). The prime global targets for eliminating viral hepatitis are a 90% reduction in new cases and a 65% reduction in related deaths. These global disease elimination targets link to a range of service-level targets concerning intervention coverage in relation to diagnosis, prevention and treatment. The Strategy, for the first time in global health policy, imagined "a world where viral hepatitis transmission is halted" (WHO, 2016b:.21).

Through their entanglements with targets, modelled projections equip and format transactions in intervention and policy (Callon, 1998), thereby shaping the viral elimination contexts of which they are a part. Models and targets thus work together as 'arrangements of prediction' to make-up viral

elimination futures (Schubert, 2015). We can trace, for example, modelled evidence of treatment-as-prevention into global as well as national viral elimination strategies (WHO, 2014, 2016b; Commonwealth of Australia, 2016; All-Party Parliamentary Group on Liver Health, 2018; Health Protection Scotland, 2019). Moreover, not only do models shape the invention of targets but they are put-to-use and calibrated in relation to these as a means of projecting the interventions and investments required to actualise elimination promise (Razavi et al., 2017, 2019; Scott et al., 2017, 2018; Ward et al., 2018; Gountas et al., 2018; Hefferman et al., 2019; Kwon et al., 2019; Walker et al., 2019). There is then, a recursive relationship between models which evidence-make elimination potential, the invention of viral elimination targets, and models which evidence elimination progress in relation to these.

Governing

Our first point, and perhaps our main one, is that enumerations are afforded particular governing powers. The data products of meta-analyses, systematic reviews and mathematical models, for instance, generate particular potentials as evidence-making interventions regarding their relative epistemic and rhetorical value, apparent stability, objectivity and precision, data combinability, and translational mobility (Robson, 1992; Hansen and Porter, 2012; Daston and Galison, 2007; Moreira, 2007). A body of work investigates how enumerations have governmentality potential in relation to health and welfare (Rose, 1991; Porter, 1995; Miller, 2001; Shore and Wright, 2015; Merry, 2011; Davis et al., 2012; Hansen and Porter, 2012), including through targets, standards, rankings, projections, predictions, measures, metrics and audits (Castels, 1999; Power, 2007; Strathern, 2000; Sauder and Espeland, 2009; Erikson, 2012). The development of statistics and probability, in particular, has enabled enumerated governance through various measures of 'risk', which have helped create and control boundaries of 'population' and 'health' in relation to quantifiable biosocial 'norms' (Castels, 1991; Rose, 1991; Armstrong, 1995; Rowse, 2009). Enumerations, and especially projections and predictions, function to *tame* risk, chance and uncertainty, thus affording security through calculus (Hacking, 1990; Castels, 1999). As noted, "By producing information about what has not yet happened", projections "reduce social complexity and constitute problems for acting in the present" (Aykut et al., 2019: 2; Mallard and Lakoff, 2011). Enumerated projections standardise and control by closing down unknowns, as sources of dis-ease, into a governable present.

Virtual precision, vague predicates, and the 'elimination paradox'

Let us consider how enumerations enact diseases as governable. Here, we consider specifically how proportionalities have a power-of-acting. As we have noted, there are two prime WHO global targets

which constitute the elimination of hepatitis C as a public health threat by 2030: a 90% reduction in new infections and a 65% reduction in related deaths. Each of these targets afford *virtual precision* in the face of *uncertainty.* Both 90% and 65% are expressions of proportionality in relation to a ratio (90:100, and 65:100), and thus simplify the ratio of two quantities in a field (Verran, 2015; Holtrop, 2018). The numerator, which simplifies the sum of the infections or deaths being reduced, is evidence-made (and is nothing without) the denominator, which represents the whole, the total number in the field. The enumerated reality is made relationally. Percentages enact parts in relation to a whole. Elimination is constituted (in part, for there are other targets) as a percentage reduction against a population of an *unknown* absolute number of infections and deaths. The denominator is an empirical unknown in many settings, especially given the complex history of hepatitis C transmissions in diverse populations and how the totality of absolute cases (embodied in actual people) remain hidden from the gaze of epidemiology and diagnostic testing (Foura et al., 2018; Grebely et al., 2019). Percentages focus attention on "the possibility of de-/increase of the *proportion* rather than on the *constituents* themselves or the mathematics of their relation" (Holtrop, 2018: 9; emphasis added). Proportionality is a means to governing uncertainty at distance, here in relation to multiple unknowns regarding referent cases and their relations. The uncertainties of how to 'actually' enumerate hepatitis C incidence and death in quantities that are measurable (Larney et al., 2015; Trickey et al., 2019; Grebely et al., 2019), as well as the complexities of social and material relations which affect local patterns of incidence and illness, are tamed (masked) through proportionality.

Verran (2015) notes that proportionalities can offer technical solutions to the 'sorites paradox', also known as the paradox of heaps and piles, which arises in vague predicates, such as when does a heap or pile, such as a pile of rice, no longer become a heap or pile, as units are progressively taken away? Viral elimination also arises in vague predicates. When does elimination occur? How many cases of infection have to be removed for elimination to come into being? Conversely, when does elimination cease to exist? The WHO targets do not constitute viral elimination in relation to absolute numbers or thresholds. For instance, viral elimination is not articulated as maintaining *zero cases* globally (disease eradication) or in epidemiological terms as the *stopping of transmission* in a defined space or time (disease elimination) (Dowdle, 1998; Dore, 2018). Proportional targets solve an *elimination paradox* in the face of case and threshold imprecision. They render a "vague whole" into "specific units" as a means to enact a "governance" (Verran, 2015: 370). A *new entity* of elimination is refashioned, one *materially different* from past epidemiological definitions (Dowdle, 1998). This new version of disease elimination is constituted as an unknown number of infections deemed 'manageable' and 'acceptable' relative to public health 'threat' (WHO, 2016b; Dore, 2018). This vague set of predicates is nonetheless

performed as a *virtual precision*, thus enabling governmentality potential, through its enumeration as *a proportion*. The proportion *itself* becomes, and makes certain enough, elimination. As we have noted elsewhere of numerical targets, enumerations do not need empirical precision to perform authority (Lancaster, Rhodes and Rance, 2019). We have then, a case of enumerated projections governing a material present in relation to an imagined future through practices of virtual precision giving rise to *virtual elimination*.

Elimination governance, states, and citizenship

We can further trace how global viral elimination strategy and targets quantify and qualify in particular ways. The WHO Global Health Strategy qualifies viral hepatitis as a visible and major problem worthy of global attention in relation to universal standards of health and sustainable development. This, in combination with the invention of apparently quantifiable elimination targets, transforms the object of hepatitis C from a matter of dis-ease to a technical controllable problem of vital significance (Lancaster, Rhodes and Rance, 2019). Enumeration performs a problem that 'counts' at the same time as making it amenable to control through *counting*. Furthermore, numerical targets enact particular realities in the futures they project, which impact *in the present*, including through policy and intervening (Michael, 2000). We should therefore ask 'what kind worlds do elimination targets make?', and put another way, 'what kind of *now* is made possible through practices of elimination futuring?'.

Here, our example accentuates how numerical targets contribute to constituting a world in relation to *viral elimination*, wherein targets become technologies of transnational governance in relation to a global standard (Hansen and Porter, 2012). This is not a neutral process for it makes up populations, states, geographies and citizenships in particular ways in relation to particular enumerated values. It is also a relational process in which the governing effects of global targets are made possible through their connections in a *hinterland* of practices (Law, 2004, 2009) which combine to coordinate a 'glocal' viral elimination reality, including through nation-state sign-ups to global strategies, pharmaceutical industry and government relations, treatment investments and scale-ups, diagnostic and testing innovations, community campaigns, and implementation science. A global 'race' to eliminate hepatitis C is held in place by this hinterland of viral elimination practices (Lancaster and Rhodes, 2020). We can see how nation-states and other territories are made 'accountable' through targets in relation to the global elimination race, enacting *elimination citizenship*. This new world is constituted of *elimination states*, wherein territories are refashioned as parts in relation to an imagined whole constituted by an 'acceptable' level of reduced infection (Dore, 2018). Many territories fall short of inclusion against this

new norm. The focus of targets on shifts in proportionalities (90% reductions in infections and 65% reductions in deaths) deflects attention from the complexity of the social-material relations enabling or disabling such change, especially considering the rich diversity of territories making-up the globe. Rather, attention shifts to the constitution of nation-states as 'elimination-states' in relation to their relative positioning against virtual elimination targets (90% and 65%) in abstract measures of elimination time (usually 2020 or 2030). Models project the progress of nation-states against these virtual measures, and whether they appear to be "on track", "ahead", or "unlikely" to meet global targets in time (Kwon et al., 2019; Walker et al., 2019; Scott et al., 2019; Razavi et al., 2019).

Figure 1, for instance, qualifies the world in relation to viral elimination targets. Based on modelling and epidemiological data synthesised by the Polaris Observatory (2019), 95 countries are marked red with elimination projected as "unachievable", 10 are marked amber and "working towards" elimination, and six are green and "on track". Half as many countries are "on track" according to these data in 2019 than in 2017 (See also Razavi et al., 2019). At the time we submitted this paper for publication, the UK, Australia and Georgia were among the countries projected as being "on track" to achieve the WHO elimination targets by 2030 (Razavi et al., 2019). By the time we came to revise our paper, these countries were projected, on account of 2019 data and changing treatment rates, to achieve the WHO incidence target by 2038, 2040 and 2041 respectively (Polaris Observatory, 2019). Different models produce different elimination states in space and time (Ward et al., 2018; Walker et al., 2019; Kwon et al., 2019). The numerical constitution of elimination states affords nations and governments a relative capital in a global field, but is not stable, with multiple elimination realities co-existing as well as in friction with one another (See also below). Figure 2 similarly qualifies nation-states in Africa in relation to quantifications of viral elimination. Again, states are constituted in relation to their relative success (green) or failure (red) on a "scorecard" of viral hepatitis elimination potential. On the indicator relating to WHO global viral hepatitis testing targets, all 42 countries submitting data are scored "not on track", with only eight countries indicated as showing progress in developing national hepatitis treatment programmes.

Insert: Figures 1 and 2

The articulation of targets as accountability devices in relation to a universal standard is also explicit in WHO's 2019 progress report on global viral elimination which is sub-titled "Accountability for the global health sector strategies, 2016-2021" (WHO, 2019). The mixed success in reaching global targets in relation to hepatitis, HIV and sexually transmitted infections is used as a platform to advocate for

action to 'accelerate towards elimination' and as an 'opportunity to fill gaps in implementation' so as to 'reach the targets' (WHO, 2019: 2). The report shows the viral hepatitis elimination targets in light green to indicate "on track, with gaps", though in relation to hepatitis C there are no percentage reductions calculated against the twin targets of reduced infections (of 90% by 2030) and deaths (of 65% by 2030). Subsumed within a singular category of viral hepatitis, the report produces a "scorecard" which indicates the global viral elimination targets in green and "on track", despite the data indicating a decline in incident infections being unavailable for hepatitis C (WHO, 2019: 24). We see the performative potential of targets as a mobilising resource for audit, accountability and action, ordering the world in relation to hepatitis C in particular ways, even in the relative absence of empirical evidence. Here, targets enact a virtual precision through the *performance* of evidence-based intervention, but do so with incredible latitude. With hepatitis C targets unsubstantiated given the unavailability of numerical estimates, it is the *targets themselves* which are given life to act and which do the *qualification* work. Targets, because they qualify as well as enumerate, do not always need numerical data to perform.

To further illustrate our points about the power-of-acting of global targets, we can note how numerical targets are incorporated in community advocacy campaigns. Elsewhere, we have traced how targets are mobilised in visualisations of viral elimination as part of the World Hepatitis Alliance "NOhep" campaign (Lancaster and Rhodes, 2020). The NOhep movement seeks to act as an "accountability and advocacy tool ensuring governments take necessary measures to the targets outlined in the WHO Global Health Sector Strategy" (NOhep, 2018a). Figure 3 gives an illustration (NOhep, 2018b). In this visualisation, the actors which qualify elimination potential (through different kinds of intervening) are bounded between a baseline of quantification and a numerical target with quantified outcome. Elimination – which results from the various actors and actions coming together – requires enumeration, and more specifically *targets*, to become known. Other infographics in the campaign also enact elimination actors as enumerated entities against numerical targets (see: NOhep, 2018b). These enumerations do their work, affecting power, through the campaign without mobilising 'actualised' numbers. Taken together, we can see that numerical targets are afforded governmentality potential through their enactments in different actor networks – epidemiology, modelling, policy, and community – and that the power of numbers resides in their *relations*.

Insert: Figure 3

Affecting

Appreciating enumerations as forces of governance accentuates how models and targets generate effects in ways that extend beyond their original modes of calculation. Our next point emphasises that the knowledge produced in mathematical models circulates beyond the model into new actor networks without necessarily transporting all of its methodological apparatus and epistemological assumptions (Callon, 2007; Latour, 1987; Law, 2009). Enumerations have material life and form beyond their calculus. How models give life to numerical targets of disease elimination, which then generate agency and authority of their own, is an example (see above). Indeed, enumerations are especially mobile objects, partly enabled by their enactment as 'universals' in an assumed common mathematical language said to translate across contexts (Porter, 1995). It is therefore important to ask how enumerations adapt and transform according to how, where, and for what purpose they travel, especially as they circulate from their original fields of inscription (Latour, 1987). This means that we do not treat enumerations as 'immutable mobiles' of singular and fixed precision but as 'mutable mobiles' of multiple potential with unforeseen effects (Latour, 1987; Law, 2004; Myers, 2015). Critically, this accentuates enumerations materialised as *situated concerns*. Enumerated projections escape, and extend beyond, their mathematical models and targets as they are actualised locally in relation to matters of social and political *concern*, as well as *desire*. This brings us to appreciate models as devices of *anticipation* and *affect* and not merely of reasoned calculus (Myers, 2015). What enumerations *do* is contingent upon how they *affect*, and are *affected* by, the material worlds in which they circulate. This accentuates two things: a multiplicity of enumeration effect potential beyond matters of fact and calculus; and potential frictions in how scientists and other actors engage with, and make use of, projections.

Material transformations

We have proposed that a foundational moment in the evidence-making of viral elimination is the modelled projection of 'treatment-as-prevention'. The first such published model theorised that hepatitis C elimination was not possible without population-level risk reduction, necessitating treatment at sufficient coverage to attenuate the effects of re-infections among people who continued to inject drugs (Zeller et al., 2010). A second model, published in 2011 (Martin et al., 2011), then modified in light of altering treatment cures rates (Martin et al., 2013), was "the first" to transform hepatitis C from merely treatable to an object preventable at "modest" and "achievable" treatment rates (Martin et al., 2011: 1141). This latter model projected, for instance, that an annual treatment rate of just 20 infections per every 1000 persons who injected drugs resulted in a 62% reduction in prevalence after 10 years in a chronic prevalence scenario of 20% (Martin et al., 2011). This model has taken flight, helping to establish a treatment-as-prevention standard for the field.

Through the evidence made by the model, treatment-as-prevention has become enacted as *doable* and *within reach*, an *anticipated reality*, and this has afforded the object of treatment-as-prevention a power-of-acting and capacity for travel (Rhodes and Lancaster, 2020). Through anticipation, we move from mere *possibilities* (theoretical propositions) to *potentialities* (futures felt in the now). The model of treatment-as-prevention is actualised into the immediate present through rapid policy and intervention transformations. For instance, clinical practice guidelines rearticulate treatment as an object of prevention (WHO, 2014, 2016d; EASL, 2015, 2016), and national strategies draw on modelled projections to set viral elimination targets (Commonwealth of Australia, 2018; Health Protection Scotland, 2019). Multiple models have flowed, transforming their field of attention beyond mere treatment-as-prevention to *viral elimination* potentials. Models move around the globe to evidence elimination states and futures, while contributing to target setting and calibrating projections in relation to these (see above).

Upon release from its model, therefore, the object of treatment-as-*prevention* entangles as affective matter into *elimination concern*. Through its travels into new actor networks enumerated treatment-as-prevention becomes something more, a new entity, a re-assembled object of *elimination* with the power to affect, and be affected by, its emergent context. The viral elimination assemblages, in which models and targets entangle as technologies of anticipation, incorporate the fervour of community, media, policy and industry excitement which makes up the 'race to eliminate' (Lancaster and Rhodes, 2020), and generates affective flow (Adams, Murphy and Clarke, 2009; Myers, 2015; Schubert, 2015). Treatment-as-prevention makes new attachments as it is 'let go' from its mathematical origins (Gomart and Hennion, 2000; Rhodes and Lancaster, 2020). The power-of-acting of enumerated projection is *moved* in its materialisations, from maths and calculus to action and affect, always becoming more than 'just a number'.

Consider, for instance, the following headlines released from the National Health Service of England as technologies of anticipation which energise viral elimination concern in the global race to eliminate: "Our aim is to rid England of the hepatitis C virus"; "NHS England sets out plans to be first in the world to eliminate Hepatitis C"; "NHS England plans to eliminate Hepatitis C in England by 2025, five years earlier than World Health Organisation goals"; and "The NHS will find and cure tens of thousands more people with hepatitis C as part of a ground-breaking deal that could help England become the first country in the world to eliminate the deadly virus" (NHS England, 2019a,b,c,d). Enumerated projections generated by mathematical models live among variable forms of projection beyond science – targets, policy proposals, advocacy interventions, community actions, hopes, desires – which

entangle together to make up an assemblage of potential embodied as anticipation. This hits home our key point: when appreciated as performative actors, enumerations are not "stable states" but "relational beings" (Verran, 2015: 367).

Qualculation and anticipation

What lessons can we draw from noticing that enumerations take flight beyond their calculative origins? First, we can appreciate that enumerations are made up in *qualifications* and not only quantifications. A calculation is not merely arithmetical in form (Callon and Law, 2005). The materialisation of enumerations in situated practices – from community actions to national targets and global policies – is a process of *qualification*. Upon leaving their laboratories of production, enumerations are qualified in one way or another as *matters-of-concern* in relation to the epistemological claims made about them, the values and effects they afford, and how they are put-to-use by knowledge consumers (Moreira, 2007). Following Callon and Law (2005), models and targets are best understood as *qualculations*: they rely upon and generate qualitative judgements and qualifications, and they work to produce qualified as well as quantified abstractions and projections.

Second, we can consider the potential for *non-qualculability*. One form of non-qualculability which has a bearing on the power-of-acting of models and targets is *rarefaction* (Callon and Law, 2005). This removes the resources and relations required for qualculus, through a 'letting go' in favour of affect, such as embodied passion, emotion, attachment, suffering, and feeling (Gomart and Hennion, 2000). We are proposing that *anticipation* is one such affect generated by enumerated projections. Anticipation reaches beyond 'evidence-based' calculation. In their 'letting go' as affective matter, projections alter metaphysically as well as metaphysically alter their present (Verran, 2015). Projected futures of great promise, of hope, of game-changing potential, of a new world without infection, generate affects which are felt in, and make, the present. As we noted earlier, models and targets govern as forms of anticipatory regime, for they orientate to a future which makes responses in the now (Adams, Murphy and Clarke, 2009; Mallard and Lakoff, 2011; Guston, 2014). Thinking of enumerated projection as qualculation and as affective matter pushes us beyond calculus to the incorporation of vital concerns. It helps us notice the work that enumerations do beyond maths and science. Treating enumerations as qualculations and affects also attends to the *latitude* afforded to models and targets as they travel as *virtual precisions* into practices (see above). We propose that it is this flexibility, this relative release from empirical actuality, this letting go, that affords enumerations *movement* in how they enact 'evidence' in ways which matter (Hacking, 1995; Sismondo, 1999; Myers, 2015). This is to say, that what matters in practice is how models and targets *move things* (affects,

people, policies) to *make things* (like viral elimination) happen. There is a multiverse of evidences and effects generated by models which are rarely considered within the world of evidence-based calculus.

Enacting

Lastly, we extend our point about enumerations as 'relational beings' by honing attention to how the methods of models themselves act as performative devices. We see the methods of enumerated projection as *object making machines* (Mackenzie, 2006). This thinking focuses attention on how the calculative practices of models (and other forms of synthesis and simulation) do not merely re-assemble the data upon which they draw, but *enact new entities* through their enumerations. Following Michel Callon's work on the performativity of economic models (2007), we draw attention to two translational processes in modelling practices. First, there is a process of *detachment* of entities arranged into a different single space. This involves disentangling data from their networks, domains and sources into a new network, or database, to create the model. Second, there is the implementation of a *common language* or operating principle within this new data space which enables comparison across the incorporated data which have been drawn from multiple calculative spaces. Both these steps involve *calculation* and *qualification* (that is, qualculation), wherein data is handled and presented in *new ways* to enact enumerated entities of a *different kind* (Callon, 2007; Moreira, 2007; Bauer, 2013; Verran, 2015).

In models and simulations there is considerable work involved to bring "heterogeneous bits and pieces" into a "patterned network that overcomes their resistance" to produce a new "end product" (Law, 1992: 381). Removing ambiguity and complexity from data elements fed into a model, for instance, involves 'fixing' categories through processes of 'stabilisation' and 'disambiguation', and these are necessary qualification steps to make data categories and models work (Rapp, 1999: 208; Bauer, 2013). Qualifications play an important role in navigating the 'mess' of model building (Sismondo, 1999). There seems greater latitude, as well as qualification and subjective judgement, in models engaging with data subject to empirical uncertainties and in models of greater abstraction (Hacking, 1995). In their modifications – via synthesis, equations and graphical platforms – different forms of data are *on the move,* and take on additional properties, giving rise to *new entities* with new governing powers. This draws attention to enumerated projections as effects of 'within model' (and not only 'beyond model') enactment, constituted in particular 'methods assemblages' of evidence-making (Latour and Woolgar, 1979; Law, 2014).

Enumerating entities of viral elimination

The object transformations enacting hepatitis C treatment as prevention, and further, as elimination, emerge in relation to situated community and policy concerns (see above) but are also made-up *inside* the modelling. This is achieved through a qualculative process which works to detach and then re-arrange various heterogeneous enumerations into a new form. Prime among the denominators incorporated into this new numerator are quantifications of 'cure rate'. Quantifications of cure rate entangle with other data inputs of variable calculative origin and form, such as: population size; drug use initiation, cessation and duration; infection incidence and prevalence; intervention effect and coverage; and risk. All of these quantifications are subject to qualifications, especially in the face of their empirical uncertainty, and are managed through extrapolations, approximations, hypotheticals, negotiations and subjective judgements.

In this journal issue, for instance, is an example of a model projecting hepatitis C prevention impact in Tanzania where few of the quantified inputs originated in local calculations, many were products of subjective judgement, and some were not based in enumerations at all (Scott et al., 2020). DAA treatments were not available in this setting, and so the model assumed that treatment commencement "will occur for 80% of people following diagnosis, based on the WHO target, which was considered feasible due to the simplicity of the new treatments" (Scott et al., 2020). Here, the model imports a *global target* to act as data in the absence of any quantifiable indicator. As we have argued above, quantifiable targets do not need 'actual numbers', or numerical precision, to make their performances 'count', that is, to work as projections of a future viral elimination reality. And as models shift to projecting viral elimination potentials, they fold in projected targets (of unknown veracity and precision locally; see above) into their making of new projections (Razavi et al., 2017, 2019; Fraser et al., 2018; Kwon et al., 2019; Scott et al., 2018; Ward et al., 2018; Gountas et al., 2018; Hefferman et al., 2019; Walker et al., 2019). We emphasise that models are always doing *ontological work* to *enact* new entities (and realities) through their qualculative moves, rather than corresponding to pre-existing data inputs (whatever their veracity) or to an anterior reality.

Let us give brief mention to two further examples of 'within model' enactment. First, we can re-visit the model of treatment-as-prevention (Martin et al., 2011). What affords this model its power-of-acting in constituting viral elimination as an 'anticipated reality' that is felt 'within reach' can be located *in the maths*. The model calculates treatment engagement rates differently to previous attempts to model treatment-as-prevention (Zeller et al., 2010). Rather than assuming a set percentage of a population treated each year, which results in treating increasingly fewer people as the pool of infections decline, the model works with a rate (for instance, 20 treated infections per

1000 persons who inject drugs) which assumes treating the *same number* of people each year from the denominator population for a set period, which generates *projections of smaller* and *more manageable* numbers of treated cases required to bring about an overall prevention effect. The elimination potentials afforded by the model are embodied within its methods assemblage and not only in the assemblages of viral elimination which give life to these enumerations upon their release.

Next, we can consider the example of an interim evaluation of the hepatitis C elimination programme in Georgia (Walker et al., 2019). Here, modelling moves a future potential into an *evaluation*, a judgement in the now, on the basis of projecting the prevention impacts of past treatment rates into a future, which is indexed in relation to set viral elimination targets. The model projects a short fall, despite large impacts, in prevention effects, estimating the need for an approximate four-fold increase in future treatment rates (from 1,000 to over 4,000 patients initiating treatment per month) to meet national hepatitis C prevention targets by 2020. The study offers a dynamic model which associates rates of decline in hepatitis C incidence with a diminishing prevalence of the population at risk (people who inject drugs), which *pre-dated* the implementation of the national viral elimination programme, and which enhances the prevention impact of treatment in the infected population (which also includes iatrogenic infections) going forwards (Walker et al., 2019: 8). In announcing publication of the projections that Georgia will be "unlikely" to meet its national elimination targets of 2020 but is "nevertheless still on track" to meet the WHO elimination targets of 2030, the lead modeller speculates: "We evaluated the incredible scale-up of treatment for hepatitis C and progress towards elimination in Georgia. Will they be the first country to reach the WHO HCV elimination target?" (Twitter, 2019). This model projects differently to others, including the non-dynamic models of the Polaris Observatory (See Figure 1) which indicate that Georgia will not meet the WHO elimination incidence targets until 2041, despite previous projections that Georgia was 'on track'. It can be difficult to tell, especially for non-modellers, how differences in projections are effects of calculation input. Commenting on the different projections produced by the models, one speculation proffered, in a Twitter conversation involving modellers, is that "the key part" of the dynamic model (Walker et al., 2019) was "fitting the transmission model to show how the population of people who inject drugs is changing in Georgia" which "makes a huge difference to the path of elimination that is not captured in Polaris models" (Twitter, 2019). In this example, we can appreciate how 'within model' practices might shape quantifications relating to the dynamics of the denominator populations which alter elimination projections. Importantly, these qualifications are not separable from, but entangle with, 'beyond model' qualifications, here relating to how a nation-state is enacted in a global viral elimination race.

In their handling of data of different form and empirical certainty, models incorporate a mix of qualified quantifications and quantified qualifications. Hepatitis C intervention models might work to combine, for instance, empirical quantifications with values of more or less certainty (such as difficult-to-make estimates of risk group population size and risk cessation rates) with theoretical hypotheses (such as causal pathways of risk reduction), heuristics (such as cascades of care), analogies (such as comparisons between populations, contexts and countries), and policy proposals (such as targets in relation to intervention). In their blending of different data forms, in their entangling of the apparent actual and the abstract, and in their extending of the present into the future, models create *partial connections* and make *transformations* (Hacking, 1995). We therefore think of models less as devices of reflection (of objects and actualities 'out there') but of *invention* (eventuating new objects and realities 'in here'). In viral elimination models, we jump from variable cure rates of individual treatment effect – actualised empirically in particular surveys or trials, among particular populations, in particular locations – to hypothesised enumerated entities of population prevention – actualised in simulations according to new calculative routines and material realities. We move from individuals to populations, from empirics to abstracts, from presents to futures, from cure rates to incident cases, from treatment to prevention to elimination. A *metaphysical* altering occurs (Verran, 2015).

Concluding

We propose that noticing the performative work of models and targets (and other enumerations) enacts a form of hesitation (Stengers, 2018). It encourages a slowing down, a momentary stepping back in the race to eliminate viral infection, to reflect critically on the effects that projected futures make, including in the now. Through the actions and effects of models and targets, a new material order of an imagined future is being enacted. Rather than valued in relation to their previous indexical lives – for instance, in relation to trials, surveys and other empirical routines – the values of denominators in a model shift into new numerators according to a different epistemic routine as an index of the future (Verran, 2015). On their escape from models, emergent enumerations – such as new entities of treatment-as-prevention and as elimination – have the potential to take flight, to travel, to transform, to have life through their relations in material worlds as matters-of-concern which extend beyond matters of maths, fact and science. We therefore think of enumerations not as mere numbers but as *entities*, as "relational beings", which are afforded life in relation to "some actual present" in the "here and now" (Verran, 2015: 367).

Why does this matter? The proposal to think with models and targets as relational beings and as performative actors is helpful because it brings us closer to noticing what models and targets *actually do*. As we have argued, it helps us notice how they *govern*, how they *affect*, how they *enact*. That is, how they make a *material difference*. These material effects are not easily noticed by an 'evidence-based' science restricted to matters of epistemological concern (Rhodes and Lancaster, 2019a,b). Indeed, a particular epistemological concern of modellers is how to keep hold of enumerations that appear to take flight beyond the boundaries of 'evidence-based' probability (Rhodes and Lancaster, 2020). The mutability, multiplicity and transformative potential of models, and the entities they produce as they travel into new networks, is unsettling for evidence-based science. But rather than thinking of mutable enumerations as a *problem* of evidence-based science we think of this as an *affordance* to knowing and acting differently.

We propose that working with enumerations as qualculations and as affective matter invites a modelling science that does not seek to artificially separate quantification from qualification, or maths from materiality, or evidence and practice. Rather, a qualculative and affective science of modelling promises to learn from how enumerations are made and used in situated actualities, and this makes science *more real*. Thinking with models and targets ontologically, as 'evidence-making' interventions, helps appreciate how enumerations *come to be* and are *made to matter*. This, in turn, enables dialogue about the futures we are making through our science, how these govern, and the kind of futures we might wish to make. If the ways in which enumerations materialise in practices relates to situated concerns rather than empirical precisions, and if it is this which affords them their power-of-acting potential, this tells us that we need to engage with the qualculative flexibility of models and targets as ontopolitical interventions (Mol, 2002). This invites a more speculative, as well as more qualitative, science of futuring; a modelling science which also orientates to qualifications and affects, situated multiplicities of projection, and the democratisation rather than colonisation of anticipatory expertise (Stengers, 2018; Adams, Murphy and Clarke, 2009). Our focus moves from a concern for measurement to how measures are made-to-matter.

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Declarations of interest

We have no potential conflicts of interest to declare linked to this work.

References

Adams, V., Murphy, M. and Clarke, A. E. (2009) Anticipation: Technoscience, life, affect, temporality, *Subjectivity*, 28: 246-265.

All-Party Parliamentary Group on Liver Health (2018) *Eliminating Hepatitis C in England: All-Party Parliamentary Group on Liver Health Inquiry Report*, London: All-Party Parliamentary Group on Liver Health.

Armstrong, D. (1995) The rise of surveillance medicine, *Sociology of Health and Illness*, 17: 393-404.

Aykut, S. C. (2019) Reassembling energy policy: Models, forecasts, and policy change in Germany and France, *Science and Technology Studies*, 32: 13-34.

Aykut, S. C., Demortain, D. and Benbouzid, B. (2019) The politics of anticipatory expertise: Plurality and contestation of futures knowledge in governance, *Science and Technology Studies*, 32: 2-12.

Banerjee, D., and Reddy, K. R. (2016) Safety and tolerability of direct-acting anti-viral agents in the new era of hepatitis C therapy, *Alimentary Pharmacology and Therapeutics*, 43: 674-696.

Barad, K. (2007). *Meeting The Universe Halfway*. Duke.

Bauer, S. (2013) Modeling population health, *Medical Anthropology Quarterly*, 27: 510-530.

Bellerose, M., Zhu, L., Hagan, L., Thompson, W., Randall, L., Malyuta, Y et al. (2020) A review of network simulatino models of hepatitis C virus and HIV among people who inject drugs, *International Journal of Drug Policy*, 102580.

Castel, R. (1991) From dangerousness to risk. In G. Burchell, C. Gordon & P. Miller (Eds.), *The Foucault Effect: Studies in Governmentality*, Hermel Hempstead: Harvester Wheatsheaf.

Callon, M. (1998) *The Laws of the Markets*, Oxford: Oxford University Press.

Callon, M. and Law, J. (2005) On qualculation, agency and otherness, *Environment and Planning*, 23: 717-723.

Callon, M. and Numiesa, F. (2005) Economic markets as calculative and calculated collective devices, *Organization Studies*, 26: 1229-1250.

Cipriano, L. E. and Goldhaber-Fiebert, J. D. (2018) Population health and cost-effectiveness implications of a "treat all" recommendation for HCV: A review of the model-based evidence, *MDM Policy and Practice*, doi.org/10.1177/2381468318776634

Cohen, J. (2011) HIV treatment as prevention, *Science*, 334 (6063): 1628.

Cohen, M. S., Chen, Y. Q., McCauley, M. et al. (2011) Prevention of HIV-1 infection with early antiretroviral therapy, *New England Journal of Medicine*, 365: 493–505.

Cohen, M. S., Chen, Y. Q., McCauley, M., Gamble, T., Hosseinipour, M. C., Kumarasamy, N. et al (2016, Antiretroviral therapy for the prevention of HIV-1 transmission, *New England Journal of Medicine,* 375: 830–839.

Commonwealth of Australia (2018) *Fifth National Hepatitis C Strategy 2018-2022*. from http://www.health.gov.au/internet/main/publishing.nsf/Content/ohp-bbvs-1//$File/Hep-C-Fifth-Nat-Strategy-2018-22.pdf

Connolly, W. E. (2004) Method, problem, faith. In Shapiro, I., Smith, R. M. and Masoud, T. E. (Eds.) *Problems and Methods in the Study of Politics* (pp. 332-349), London: Cambridge University Press.

Dore, G. et al (2015) Hepatitis C Virus Therapeutic Development: In Pursuit of "Perfectovir", *Clinical Infectious Diseases*. 60: 1829.

Dore, G. (2018) Striving for hepatitis C virus elimination or control? *Lancet Gastroenterology and Hepatology*, 3: 295-297.

Dowdle, W. R. (1998) The principles of disease elimination and eradication, *Bulletin of the World Health Organization*, 76 (Supplement 2): 22-5.

Fraser, H., Zibbell, J., Hoerger, T., Hariri, S., Vellozzi, C., Martin, N. K. et al (2017) Sclaing-up HCV prevention and treatment interventions in rural United States: Model projections for tackling as increasing epidemic, *Addiction*, 113: 173-182.

EASL (European Association for the Study of the Liver) (2015) Recommendations on Treatment of Hepatitis C 2015, Journal of Hepatology, 63:199–236.

EASL (European Association for the Study of the Liver) (2017) Recommendations on Treatment of Hepatitis C 2016, *Journal of Hepatology*, 66: 153-194.

Falade-Nwulia, O., Suarez-Cuervo, C., Nelson, D. R. Fried, M. W., Segel, J. B. and Sulkowski, M. S. (2017) Oral direct-acting agent therapy for hepatitis C virus infection: Systematic review, *Annals of Internal Medicine*, 166: 637-648.

Fraser H, Martin NK, Brummer-Kornenkonito H, Carrieri P, Dalgard D. et al. (2018) Model projections on the impact of HCV treatment in the prevention of HCV transmission among people who inject drugs in Europe, *Journal of Hepatology*, 68: 402-411.

Foura, S. et al. (2018) Approaches for simplified HCV diagnostic algorithms, *Journal of the International AIDS Society*, 21 (Supplement 2): 17-25.

Gane, E. (2014) Hepatitis C beware - the end is nigh, *Lancet,* 384: 1557.

Gomart, E. and Henninon, A (1999) A sociology of attachment, *Sociological Review*, 47: 220-247.

Gountas, I., Sypsa, V., Blach, S., Razavi, H. and Hatzakis, A. (2018) HCV elimination among people who inject drugs: Modelling pre- and post-WHO elimination era, *Plos One*, 13: e0202109.

Grebely, J., Breuneau, J., Bruggmann, P., Harris, M., Hickman, M., Rhodes, T. et al. (2017) Elimination of hepatitis C virus infection among people who inject drugs: The beginnings of a new era, *International Journal of Drug Policy*, 47: 26-33.

Grebely, J., Matthews, G. V., Lloyd, A. R., and Dore, G. (2017) Elimination of hepatitis C virus infection among people who inject drugs through treatment as prevention, *Clinical Infectious Diseases*, 57: 1014-1020.

Grebely, J., Larney, S., Peacock, A., Colledge, S., Leung, J., Hickman, M. et al. (2019) Global, regional, and country-level estimates of hepatitis C infection among people who have recently injected drugs, *Addiction*, 114: 150-166.

Gunning -Schepers, L. J. and Van Herten, L. M. (2000) Targets in health policy, *European Journal of Public Health*, 10 (Suppplement 4); 2-6.

Guston, D. H. (2014) Understanding 'anticipatory governance', *Social Studies of Science*, 44: 218-242.

Hacking, I. (1990) *The Taming of Chance*, Cambridge: Cambridge University Press.

Hacking, I. (1995) The looping effects of human kinds. In Sperber, D., Premack, D. and Premack, A. (Eds.) *Causal Cognition* (pp 351-384), Oxford: Clarendon Press.

Hansen, H. K. and Porter, T. (2012) What Do Numbers Do in Transnational Governance? *International Political Sociology, 6:* 409-426.

Health Protection Scotland (2019) *Scotland's Hepatitis C Action Plan: A Proposal to the Scottish Government*, Glasgow: Health Protection Scotland

Heffernan, A., et al. (2019) Scaling up prevention and treatment towards the elimination of hepatitis C: A global mathematical model, *Lancet*, 393: 1319-1329.

Hellard, M. E., Jenkinson, R., Higgs, P., et al. (2012) Modelling antiviral treatment to prevent hepatitis C infection among people who inject drugs in Victoria, *Medical Journal of Australia*, 196: 638–41.

Hellard M, Doyle JS, Sacks-Davis R, Thompson AJ, McBryde E. Eradication of hepatitis C infection: The importance of targeting people who inject drugs. Hepatology. 2014;59:366–369.

Hagan LM, Wolpe PR, Schinazi RF. Treatment as prevention and cure towards global eradication of hepatitis C virus. Trends in Microbiology. 2013;21:625–633.

Hickman, M., De Angelis, D., Vickerman, P., Hutchinson, S. and Martin, N. (2015) Hepatitis C virus treatment as prevention in people who inject drugs: Testing the evidence, *Current Opinion in Infectious Diseases*, 28: 576-582.

Holtrop, T. (2018) 6.15%: Taking numbers at interface value, *Science and Technology Studies, 31*(4).

Innes H, Goldberg D, Dillon J, Hutchinson SJ. (2015) Strategies for the treatment of Hepatitis C in an era of interferon-free therapies, *Gut*, 64: 1800-1809.

Jasanoff, S. (2010) A new climate for society, *Theory, Culture and Society*, 27: 233-253.

Kwon, J. A., Dore, G. J., Grebely, J., Hajarizadeh, B., Guy, R. Cunningham, E. B. et al (2019) Australia on track to achieve WHO HCV elimination targets following rapid initial DAA treatment uptake: A modelling studt, *Journal of Viral Hepatitis*, 26: 83-92.

Lancaster, K., Rhodes, T. and Rance, J. (2019) "Towards eliminating viral hepatitis": Examining the productive capacity and constitutive effects of global policy on hepatitis C elimination, *International Journal of Drug Policy*, doi: 10.1016/j.drugpo.2019.02.008.

Lancaster, K. and Rhodes, T. (2020) Visualising the promise of disease elimination futures: The case of hepatitis C (unpublished paper; available on request).

Landström, C., Whatmore, S.J. and Lane, S.N. (2011) Virtual engineering: computer simulation modelling for flood risk management in England. *Science Studies*, 24: 3-22.

Larney, S., Grebely, J., Hickman, M., De Angelis, D., Dore, G. and Degenhardt, L. (2015) Defining populations and injecting parameters among people who inject drugs: Implications for the assessment of hepatitis C treatment programs, *International Journal of Drug Policy*, 26: 950-957.

Larney, D., Peacock, A., Leung, J., College, S., Hickman, M., Vickerman, P. et al (2017) Global, regional and country-level coverage of interventions to prevent and manage HIV and hepatitis C among people who inject drugs: A systematic review, *Lancet Global Health*, 5: e1208-e1220.

Latour, B. (1987). *Science in Action,* Harvard University Press.

Latour, B. (2004) Why has critique run out of steam? From matters of fact to matters of concern, *Critical Inquiry*, 30: 225-248.

Latour, B. and Woolgar, S. (1979) *Laboratory Life: The Social Construction of Scientific Facts*, London: Sage.

Law, J. (2004) *After Method,* London: Routledge.

Law, J. (2009) Seeing Like a Survey. *Cultural Sociology, 3*: 239-256.

Law, J. (2012) Collateral realities, In F. D. Rubio & P. Baert (Eds.), *The Politics of Knowledge* (pp. 156-178), Oxon: Routledge.

Law, J. and Singleton, V. (2005) Object lessons, *Organization*, 12: 331-355.

Mackenzie, D. (2006) *An Engine, Not a Camera: How Financial Models Shape Markets*, Cambridge, MA: MIT Press.

Mallard, G. and Lakoff, A. (2011) How claims to know the future are used to understand the present, in Camic, C., Gross, N. and Lamot, M. (eds) *Social Knowledge in the Making*, Chicago: University of Chicago Press (pp. 339-378).

Martin, N. K., Vickerman, P. and Hickman, M. (2011) Mathematical modelling of hepatitis C treatment for injecting drug users, *Journal of Theoretical Biology*, 274: 58–66. 22.

Martin, N. K., Vickerman, P., Grebely, J., et al. (2013) HCV treatment for prevention among people who inject drugs: Modelling treatment scale-up in the age of direct-acting antivirals, *Hepatology*, 58: 1598.

Martin, N. K., Hickman, M., Hutchinson, S. J., Goldberg, D. J. and Vickerman, P. (2013) Combination interventions to prevent HCV transmission among people who inject drugs: modelling the impact of antiviral treatment, needle and syringe programmes, and opiate substitution therapy, *Clinical Infectious Diseases*, 57 (Supplement 2): S39–S45.

Martin, N. K., Vickerman, P., Miners, A. et al. (2012) Cost-effectiveness of hepatitis C virus antiviral treatment for injection drug user populations, *Hepatology*, 55:49–57.

Martin, N. K., Vickerman, P., Dore, G. J., Grebely, J., Miners, A., Cairns, J. et al. (2016) Prioritization of HCV treatment in the direct-acting antiviral era: An economic evaluation, *Journal of Hepatology*, 65: 17-25.

Martin, N. K., Vickerman, P. and Hickman, M. (2017) How to eliminate HCV infection by antiviral treatment, *Journal of Hepatology*, 67: 5-6.

Mccann, E. and Ward, K. (2012) Policy assemblages, mobilities and mutations, *Political Studies Review*, 10: 325-332.

Michael, M. (2000) Futures of the Present: From Performativity to Prehension. In N. Brown, B. Rappert & A. Webster (Eds.) *Contested Futures: A Sociology of Prospective Techno-science* (pp. 21-42), Aldershot: Ashgate Publishing.

Miller, P. (2001). Governing by numbers: Why calculative practices matter. *Social Research, 68*(2), 379-396.

Moreira, T. (2007) Entangled evidence: Knowledge making in systematic reviews in healthcare, *Sociology of Health and Illness*, 29: 180-197.

Mol, A. (1999). Ontological politics. A word and some questions. *The Sociological Review, 47*(S1), 74-89.

Mol, A. (2002). *The Body Multiple: Ontology in Medical Practice*, Durham Duke.

Myers, N. (2015) *Rendering Life Molecular: Models, Modelers and Excitable Matter*, London: Duke University Press.

NOhep (2018a). FAQs Retrieved 22 November, 2018, from http://www.nohep.org/faqs/

NOhep (2018b). NOhep Resources Retrieved 22 November, 2018, from http://www.nohep.org/campaigns/resources/?type=7

NHS (National Health Service) (2019a) Our Aim is to Rid England of Hepatitis C Virus, July 29 2019 (accessed October 12, 2019), https://www.england.nhs.uk/blog/our-aim-is-to-rid-england-of-hepatitis-c-virus

NHS (National Health Service) (2019b) NHS England Sets Out Plans to be the First in the World to Eliminate Hepatitis C, January 29 2019 (accessed October 12, 2019), https://www.england.nhs.uk/2018/01/hepatitis-c-2/

NHS (National Health Service) (2019c) NHS England's Plan to Eliminate Hepatitis C Decisviely Backed by High Court, January 19 2019 (accessed October 12, 2019)https://www.england.nhs.uk/2019/01/nhs-englands-plan-to-eliminate-hepatitis-c-decisively-backed-by-high-court/

NHS (National Health Service) (2019d) NHS England Strikes World Leading Deal to Helo Eliminate Hepatitis C, April 30 2019 (accessed October 12, 2019), https://www.england.nhs.uk/2019/04/nhs-england-strikes-world-leading-deal-to-help-eliminate-hepatitis-c/

Pitcher, A. B., Borquez, A., Skaathun, B. and Martin, N. (2018) Mathematical modelling of hepatitis C virus prevention among people who inject drugs: A review of the literature and insights for elimination strategies, *Journal of Theoretical Biology*, 21: 194-201.

Polaris Observatory (2019) Countries on track to achieve WHO elimination targets, https://cdafound.org/polaris/ (accessed January 14, 2020).

Puig de la Bellacasa, M. (2017) *Matters of care*, University of Minnesota Press.

UNAIDS (2014) *90-90-90: An ambitious Target to Help End the AIDS Epidemic*, Geneva: Joint United Nations Programme on AIDS.

Race, K. (2014) Complex events: Drug effects and emergent causality, *Contemporary Drug Problems*, 41: 301-334.

Rapp, R. (1999) *Testing Women, Testing the Fetus*, New York: Routledge.

Razavi, H., Robbins, S., Zeuzem, S., Negro, F., Buti, M., Duberg, A-S et al. (2017) Hepatitis C virus prevalence and level of intervention required to achieve the WHO targets for elimination in the European Union by 2030: A modelling study, *Lancet Gastroenterol Hepatology*, 2: 235-236.

Razavi, H., Sanchez Gonzalez, Y., Yuen, C. and Cornberg, M. (2019) Global timing of hepatitis C virus elimination in high-income countries, *Liver International*, doi: 10.1111/liv.14324.

Rhodes, T. and Lancaster, K. (2019a) Evidence making interventions in health: A conceptual framing, *Social Science and Medicine,* 238: doi.org/10.1016/j.socscimed.2019.112488.

Rhodes, T. and Lancaster, K. (2019b) Evidence-making hepatitis C: Towards a science that knows more carefully, *International Journal of Drug Policy*, 72: 40-46.

Rhodes, T. and Lancaster, K. (2020) Excitable models: Enumerated projections and the making of futures without disease (unpublished paper; available on request).

Rose, N. (1991) Governing by numbers: Figuring out democracy. *Accounting, Organizations and Society, 16*: 673-692.

Rowse, T. (2009) The ontological politics of 'closing the gaps'.,*Journal of Cultural Economy, 2:* 33-48.

Sismondo, S. (1999) Models, simulations, and their objects, *Science in Context*, 12: 247-260.

Scott, N., Hellard, M. and McBryde, E. S. (2016) Modeling hepatitis C virsu transmission among people who inject drugs: Assumptions, limitations and future challenges, *Virulence*, 7: 201-208.

Scott, N., McBryde, E, Thompson, A., Doyle, J. and Hellard, M. (2017) Treatment scale-up to achieve global HCV incidence and mortality elimination targets: A cost-effectiveness model, *Gut*, 66: 1507-1515.

Scott, N., Ólafsson, S., Gottfreðsson, M., Tyrfingsson, T., Rúnarsdóttir, V., Hansdottir, I. et al. (2018) Modelling the elimination of hepatitis C as a public health threat in Iceland: A goal attainable by 2020, *Journal of Hepatology*, 68: 932-939.

Scott, N., Zameer, M., Rwegasha, J., Mbwambo, J., Lemoine, M. and Hellard, M. (2020) Upscaling prevention, testing and treatment to control hepatitis C as a public health threat in Dar es Salaam, Tanzania: A cost-effectiveness model, *International Journal of Drug Policy*, 102634.

Stengers, I. (2018) *Another Science is Possible*, Cambridge: Polity.

Trickey, A., Fraser, H., Lim, A. G., Peacock, A., Colledge, S. and Walker, J. et al (2019) The contribution of injection drug use to hepatitic C virus transission globally, regionally, and at country level: A modelling study, *Lancet Gastroenterology and Hepatology,*6: 435-444.

Twitter (2019) Retrieved from: https://twitter.com/Homie_Razavi/status/1208067743901077504 (December 21, 2019).

Verran, H. (2015) Enumerated entities in public policy and governance, in Davis, E., Davis, P. (Eds) *Mathematics, Substance and Surmise*, Springer (365-379).

Walker, J. G., Kuchuleira, T., Sergenko, D., Fraser, H., Lin, A. G., Shadaker, S. et AL. (2019) Interim effect evaluation of the hepatitis C elimination programme in Georgia: A modelling study, *Lancet Global Health*, doi.org/10.1016/S2214-109X(19)30483-8.

Ward, Z., Platt, L., Sweeney, S., Hope, V. D., Mager, L., Hutchinson, S. et al (2018) Impact of current and scaled-up levels of hepatitis C prevention and treatment interventions for people who inject drugs in three UK settings: What is requied to achieve the WHO HCV elimination targets? *Addiction*, 113: 1727-1738.

WHO (2016a) *Generic Framework for Control, Elimination and Eradication of Neglected Tropical Disease*, Geneva: World Health Organization.

WHO (2015a) *Global Technical Strategy for Malaria, 2016-2030*, Geneva: World Health Organization.

WHO (2015b) *The End TB Strategy*, Geneva: World Health Organization.

WHO (2016b) *Global Health Sector Strategy: Viral Hepatitis, 2016-2021*, Geneva: World Health Organization.

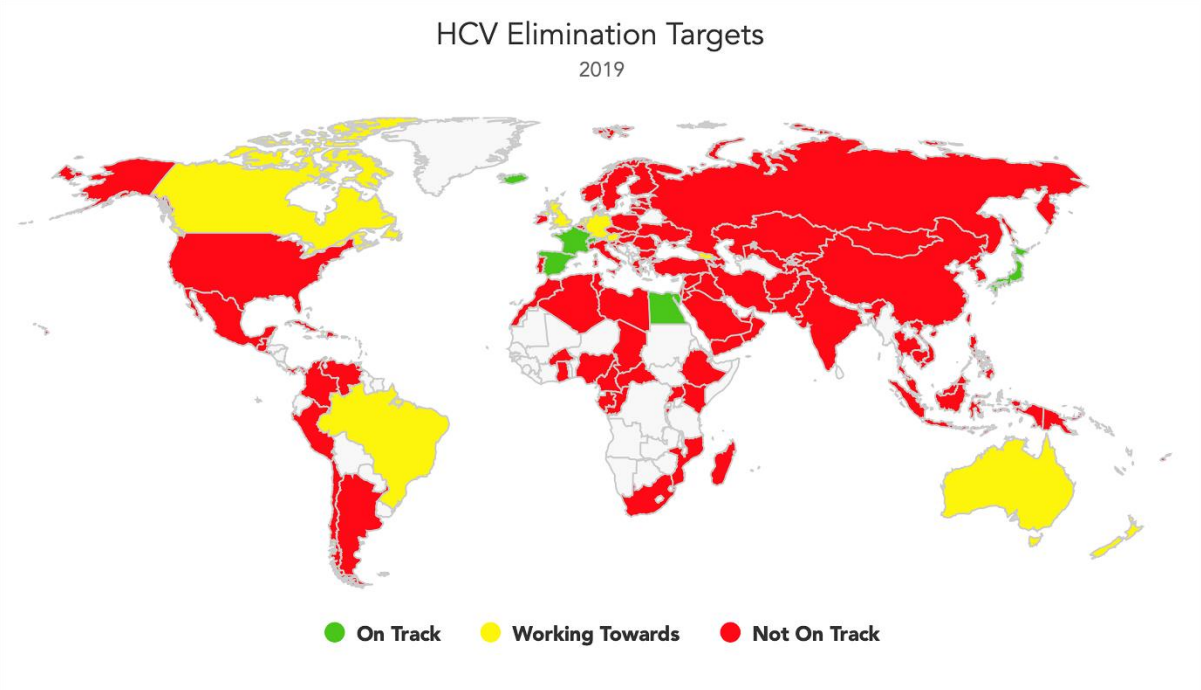
WHO (2016c) *Global Health Sector Strategy: Towards Ending AIDS, 2016-2021*, Geneva: World Health Organization.

WHO (2017d). Meeting of the International Task Force for Disease Eradication, November 2016. *Weekly Epidemiological Record, 92*(9/10), 106-116.

Zelenev, L., Li, J., Mazhnaya, A., Basu, D. and Altice, F. (2018) Hepatitis C virus treatment as prevention in an extended network of people who inject drugs in the USA: A modelling study, *Lancet Infectious Diseases*, 18: 215-224.

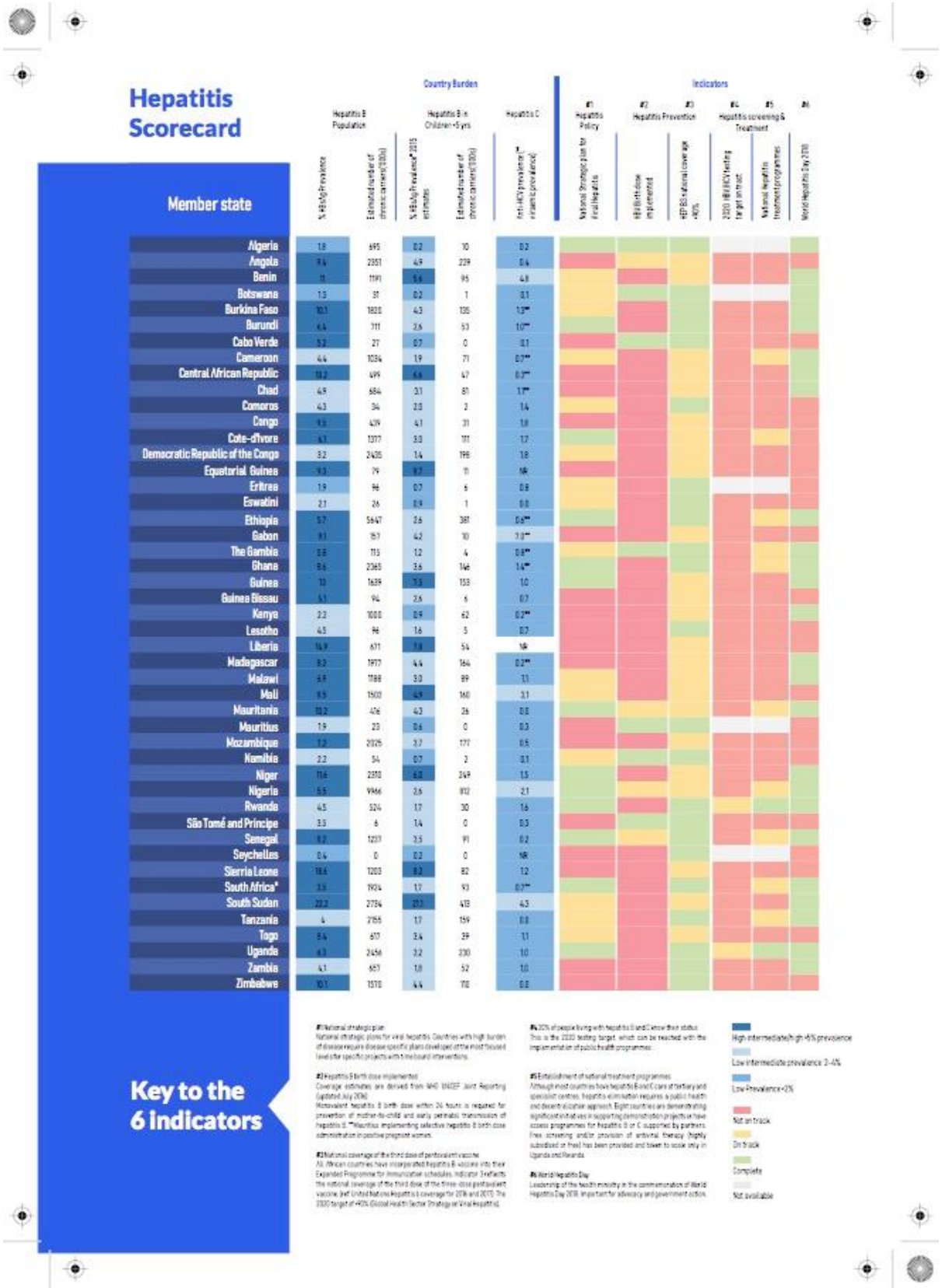
Zeiler, I., Langlands, T., Murray, J. M. and Ritter, A. (2010) Optimal targeting of Hepatitis C virus treatment among injecting drug users to those not enrolled in methadone maintenance programs, *Drug and Alcohol Dependence*, 110: 228–33.

Figure 1 Global Progress Towards World Health Organization Hepatitis C Elimination Targets



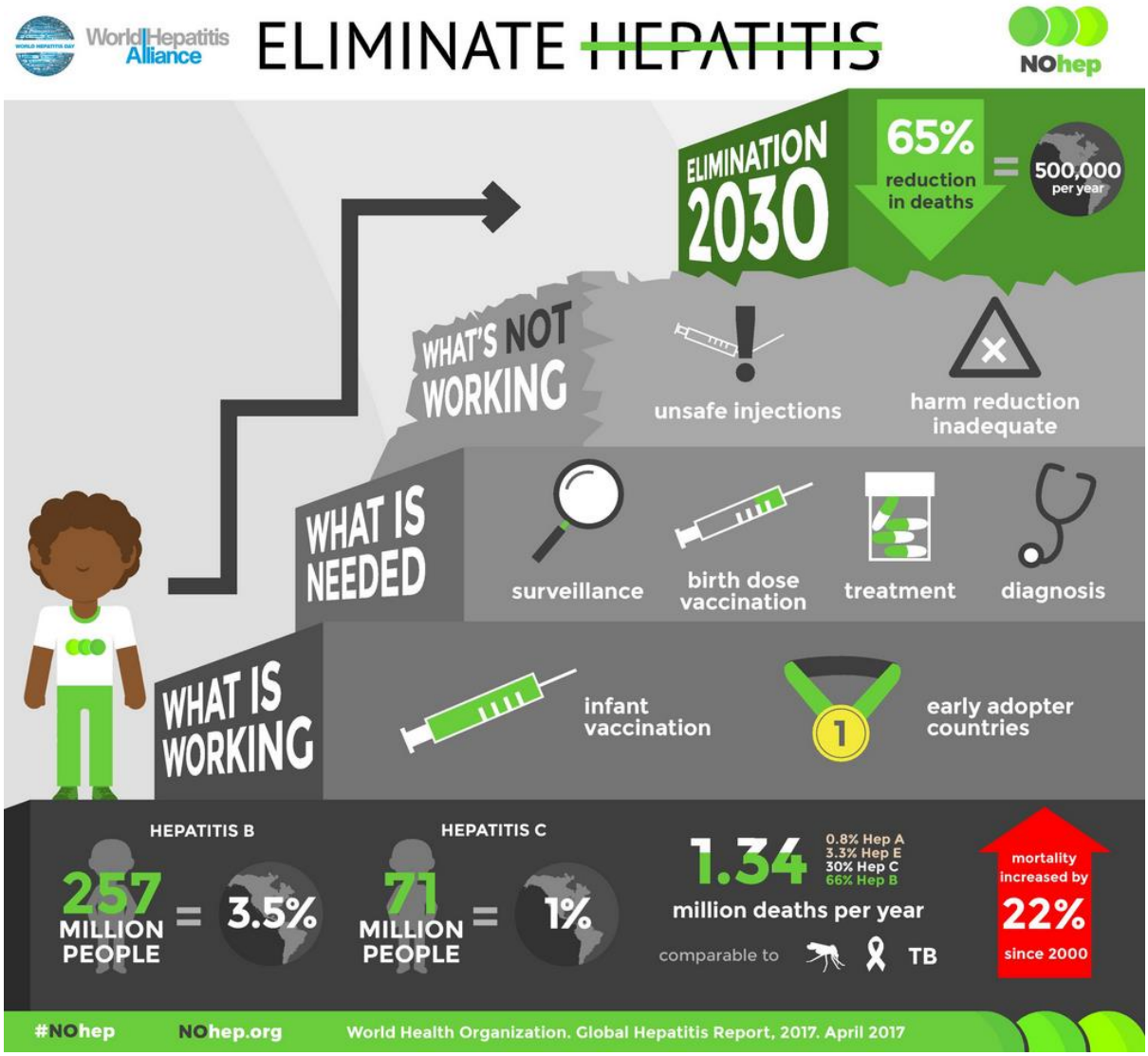
Source: Polaris Observatory, 2019: http://cdafound.org/polaris/

Figure 2 World Health Organization Hepatitis Scorecard for African Region



Source: https://www.afro.who.int/publications/hepatitis-scorecard-who-africa-region-implementing-hepatitis-elimination-strategy

Figure 3 World Hepatitis Alliance 'NoHep' Campaign



Source: https://www.nohep.org/about/