

ABSTRACT Despite being a rather recalcitrant tool, the 'Pap smear' is today the major cancer screening technology in the world. This paper examines how and why heterogeneous actors chose to advocate the Pap smear as a screen for cervical cancer in the late 1940s, and to tinker both in and far beyond the diagnostic laboratory for over 50 years to make the Pap smear 'fit' as a screening and clinical technology. Tinkerings included gendering the division of labour, attempting to automate reading of smears, juggling costs, exploring alternative screening technologies, pushing for regulation of laboratories, and settling for locally-negotiated orders of clinical accuracy instead of global standardization, still elusive today.

Making the Pap Smear into the 'Right Tool' for the Job:

Cervical Cancer Screening in the USA,
circa 1940–95

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In Silicon Valley in the early 1980s, people joked ironically that you could get any computer product you wanted fast, cheap, and/or good: pick any two. The criteria for a 'good' clinical public health screening test are similar: fast, cheap, and accurate.¹ The Pap smear, used since the 1940s to screen for endocervical cancer and potentially cancerous cellular changes on the cervix, was at its inception viewed by most actors involved as none of the above, largely due to chronic ambiguities in classification, aetiology and diagnosis. (Some would argue that it still falls short.) Yet it has become the most widely used and entrenched cancer-screening technology in the world. This paper seeks to answer *why* and *how*, over the past half-century, this technology was made into the 'right tool' for the job of cancer screening.² These questions are addressed through an examination of the contingent nature of scientific and biomedical practices.

To answer *why* the Pap smear became the right tool for the job, we must first step outside the laboratory and into the world of private non-profit charities, and their constructions of 'good' science and medicine in the years just after World War II. Here we confront what the Pap smear was the right tool for, for whom, and with what costs and benefits. To answer the *how* question, we borrow and extend Karin Knorr-Cetina's notion of 'tinkering', moving beyond the laboratory of discovery and into laboratories of diagnostic clinical practice, and relations among clinicians and

technicians.³ Multiple tinkering strategies have been used simultaneously by different collective actors, both inside and outside the cancer arena, over the past half-century, to make the Pap smear 'work' as a screening procedure. These include: (1) explicitly gendering the division of labour; (2) attempting to automate the division of labour; (3) juggling the costs of diagnostic technologies; (4) abandoning hopes of global clinical accuracy for local negotiated orders in clinical reading of Pap smears; (5) exploring diagnostic alternatives to the Pap smear; and (6) women's health and public health groups' attempts to enhance regulation of laboratories. Thus, in certain ways, our paper is about strategies for managing constraints, some of which are portable (for example, gendering the division of labour and automating the laboratory), while others are not (for instance, Pap smear classification systems embedded in local practices).

In social and cultural studies of science, technology and medicine today, supposedly simple technologies that are widely used are often understudied. The Pap smear is a very simple technology, including some kind of stick, swab or brush for obtaining cells,⁴ a slide, a slideholder, fixative, a microscope, and women's cervical cells. But this, of course, is not, in any meaningful sense, 'the whole technology'.⁵ Within recent conceptual framings, the technology of the Pap smear in the USA also includes clinicians, cytologists and patients, laboratories, the obstetrics and gynecology infrastructure, most of family and community medicine's infrastructure, virtually all state, private, and nonprofit family planning clinics, a significant proportion of community and other hospitals, county public health departments, the American Cancer Society and other foundations, the Public Health Service (and its off-shoot, the National Cancer Institute), the National Institutes of Health, and women's health activists.⁶ It is the Pap smear's initial integration into, and subsequent inextricability from, this larger biomedical technoscientific arena that makes it especially interesting in terms of the issues of the *organization* of practice raised below. That is, this technology has become so embedded in relations throughout the arena of practice within which it is used that the technology and arena have become non-fungible.⁷

Although the Pap smear arena includes all of these heterogeneous actors, ours is not a network analysis.⁸ We do not offer a 'symmetrical' account in which the Pap smear figures equally with, for example, the American Cancer Society or women consumers/patients. Rather, our account is a social-worlds analysis in which all the actors committed to or implicated by the Pap smear, both human and non-human, are analyzed and represented. These actors/actants compose social worlds joined together by their commitments in a particular arena of mutual concern. In this case, the major social worlds are different biomedical professional groups (pathologists, cytologists, technicians, public health workers), funding sources, women's health groups, and (non-human) smears and classification systems, which have come together in that segment of the wider cancer arena that is focused on cervical and uterine cancers. The social-worlds approach allows assessment of the relative power of all these

'actants' by analyzing the consequences of their activities in this shared arena. Arena analysis vividly demonstrates that there are not (necessarily) two sides but rather 'N sides', or multiple perspectives, on any technology – any of which may have consequences for relations within that arena and beyond.⁹

As symbolic interactionists, we are interested in exploring the Pap smear's meanings and practical uses for different actors within the arena of cervical cancer screening. While the Pap smear's role as a 'non-human actor' in this arena is central, we disagree with actor-network theorists that it should be analyzed symmetrically with 'human' actors, or even that all human actors should be accorded the same *analytic* stature. In our view, all actors (whether human or non-human) are assigned ontological status and significance within social worlds of meaning by the actors involved themselves, and understanding these attributions tells us much about the distribution of power in these arenas. Human actors define non-humans as 'just another actor', or as 'holding things together' in a network, insofar as the non-human actor is useful to them. Eschewing symmetry and the 'executive approach' it can spawn,¹⁰ we opt instead for asymmetry, for a political and theoretical perspective which prefers to look over some shoulders more than others in this particular arena. As engaged and implicated researchers, we situate ourselves as much less accountable to Pap smears *qua* technology, or to laboratories, than to the women who use them. Women consumers/patients at risk for cervical cancer are most affected downstream by the 'rightness' of the Pap smear as a screening technology.¹¹

While the Pap smear may be a far from ideal screening tool, it is widely viewed as the most effective currently available tool, and it is credited with dramatically decreasing American women's cancer mortality.¹² For example, from 1947 to 84, there was a 70% reduction in the mortality rate from cervical cancer, roughly from 44 to 8 per 100,000 per year.¹³ A significant proportion of the mortality reduction is attributed to use of the Pap smear as a screening technology, and it is estimated that 70% of the possible reduction in mortality through screening has already been achieved.¹⁴ It is not our intention to make claims about the Pap smear's usefulness, but rather to show how and with what costs this procedure has become the 'best' way we have to reduce women's deaths from cervical cancer.

Our account thus assumes that 'rightness' and 'wrongness' are socially constructed, relative, partial, situated and contingent.¹⁵ We therefore view claims about technological and clinical effectiveness with some suspicion. In investigating constructions of 'right' and 'wrong', it is important to examine how these definitions are deployed as artifacts in *different actors'* claims-making strategies.¹⁶ In our view, medical technologies such as the Pap smear are particularly poignant theoretical sites for feminist technoscience studies because the materialities and vulnerabilities of our bodies are made so vivid through analysis.¹⁷ Cervical cancer screening is an intimate and contested site where constructionism and materialism meet at and in women's bodies. This paper thus seeks as one of its goals to facilitate

interventions by feminist women's health activists, and to counter the recolonization of the women's health movement by mainstream medicine.¹⁸

Our account is organized as follows. We first address the issue of why the Pap smear initially became a screening technology through a brief analysis of its historical development. Even though it eventually became the 'right' tool, the Pap smear was never a 'wrong' tool historically, as it never actually became a tool until embedded in practice with a clearly stated use. But we examine some reasons why it did not become the right tool sooner, and also why it may be considered ineffective or problematic (that is, 'wrong') by some actors in terms of the criteria listed above. We next elaborate each of the major 'tinkering' strategies used to transform the Pap smear into the 'right' tool for the job of cancer prevention and early therapeutic intervention. Theoretically, we play off the commonsense assumption that technologies work relatively well and relatively easily, or else they would not be in widespread use. The Pap smear is one technology which refutes this assumption rather vividly. By detailing the multiple ways in which this technology has been massaged and manipulated to transform it into a reasonably 'right' tool, we reveal how the history of the Pap smear, like the history of most biomedical tools, is a history of compromise and making do.¹⁹ The Pap smear seems to be at an extreme end of a continuum of 'making do'. Although it is widely viewed as the best available tool, it is far from an ideal screening technology, and efforts to replace the Pap smear with alternative diagnostic procedures have, since its inception, been constantly pursued – for over half a century!

Why the Pap Smear Became the 'Right' Tool for the Job

Twentieth-century biological research on the cellular, molecular and genetic 'hows' of cancer is well known.²⁰ Less known are efforts to define the 'what, when and where' of cancer, of special concern to clinicians but also involving a wide array of biomedical researchers and other interested actors. Increasingly across the century, cancer has been handled both clinically and in terms of research by its bodily location – actually a 'cross-cutting' classification system. For example, lungs, breasts, the colorectum, the skin, and the cervix and uterus have each been sites of focus. The cervix has been especially intriguing for research due to two of its properties. First, the cervix is accessible without medically invasive (surgical) procedures;²¹ and second, through routine obstetrical and gynecological practices, there is considerable ease of access to the research materials – women.²² Since the beginning of this century, the cervix and uterus have also been of special clinical interest because of new understandings of cervical carcinogenesis. By 1912, researchers had clarified 'that surface [cellular] changes were the earliest stage of invasive cancer. Thus, the new framework, the study of early cervical neoplasia, was established'.²³ A second and reinforcing reason for clinical interest in the cervix was that, '[i]n the 1930s, 1940s, and 1950s, the number one cancer killer among

women was cancer of the uterus . . . and cervix'.²⁴ The process by which women's mortality due to cancer came to be seen as an important public health issue is intimately tied up with the history of the Pap smear as a screening tool.

But where did the Pap smear come from? George Papanicolaou, who held a Greek medical degree and a German PhD in zoology, was based in the Department of Anatomy (chaired by Dr Charles Stockard) at Cornell University Medical Center in New York City. In 1917, he published his famous paper on the vaginal smear as an indicator of the stages of the oestrous cycle in guinea pigs. For research purposes, he needed ova at particular stages of development, and he thought that perhaps these small mammals might have clear indicators of cyclicity, even if much less clear than humans. He therefore tried taking smears of cells from the vaginas of guinea pigs over time, and discovered that the precise stage of oestrus could thereby be determined.²⁵ Papanicolaou's cytological smear spread like wildfire in the reproductive sciences where, in the 1920s and 1930s, it was one of the tools of key investigations which led to the 'heroic age of reproductive endocrinology'.²⁶

In addition to its usefulness as an indicator of biological activity in small rodents,²⁷ Papanicolaou believed that the vaginal smear might also indicate something in women, and during the 1920s he 'discovered' exfoliated cancer cells in women's vaginal smears.²⁸ Probably because of Stockard's eugenic activities,²⁹ Papanicolaou initially presented his findings in 1928 to the Third Race Betterment Conference, a conclave of eugenicists, population controllers and birth controllers, as a 'New Cancer Diagnosis'. According to one colleague, his 'presentation was weakly received and almost rebuffed by many, especially the pathologists'.³⁰ His publication in the proceedings of that Conference 'was lamentable, with poorly-reproduced photographs' and such serious typographical errors as printing 'conscious cells' rather than 'cancerous cells' throughout.³¹ Papanicolaou's own assessment was that his work was poorly received due to technical problems (including lack of clarity in his early staining method), to pathologists' preference for specifically localized tissue biopsy materials (with which they were more familiar than with the free floating [exfoliated] cells of a Pap smear), and to gynecologists' interest at that time in cyclicity *per se* (rather than cancer).³²

After this disaster, Papanicolaou spent the next decade working primarily on reproductive endocrinological studies focused on the vaginal smear as a biological indicator. But in 1939, the new Chair of the Department of Anatomy at Cornell, Dr Joseph C. Hinsey, strongly urged and fully supported Papanicolaou's attention to cancer detection via the vaginal smear:

. . . together they outlined a program whereby 'the first step would be the development and establishment of its validity; the second phase would be to train others to use it; and finally an effort would be made to educate the medical profession and the public concerning what the method had to offer'.³³

New collaborations, arranged by Hinsey with gynecological pathologist Herbert F. Traut and with Andrew Marchetti of the Department of Obstetrics and Gynecology, provided Papanicolaou with adequate sources of materials.³⁴ All women admitted to the gynecological department of the New York Hospital were required to have a 'routine vaginal smear'.³⁵

As he returned to this line of work, Papanicolaou's immediate technical focus was to develop a new staining technique.³⁶ His first paper with Herbert Traut on the smear was presented in 1941, and included elaborate cautions regarding the inherent problems of this new cytological approach to cancer diagnosis.³⁷ Following that publication, the Commonwealth Fund began to support Papanicolaou's research and, over the next decade, the Fund provided a total of \$124,000, quite hefty funding for that time.³⁸ During the 1930s, the Commonwealth Fund had supported various strategies to reduce maternal mortality in the USA and, broadly viewed, Pap smear research sustained their attention to such concerns.³⁹ The two key outcomes of the research at this time were that . . .

...the vaginal smear permitted a diagnosis at a *much earlier date* than would have been possible with the biopsy technique [still preferred by pathologists] and that the diagnosis would not have been made had *routine vaginal smears of all patients* not been taken.⁴⁰

In short, while the clinical gaze had long focused on the cervix for many reasons, including cancer, Papanicolaou's work essentially provided a new high-magnification lens. This lens promised the possibility of diagnosing very early malignancies, early enough that readily available surgical and radiotherapy treatments of the day might, in fact, *eliminate* the cancer. That is, while clinical medicine did have 'magic bullets' (surgery with or without radiation), *advanced* invasive carcinoma was too large a target. But for *early localized* cervical and uterine carcinomas, there could be a 'goodness of fit' between medicine's extant magic bullets and the target. Thus one immediate value of the Pap smear screening technology was its enhancement of other extant *downstream* medical technologies including, as we shall see, the doctor's office itself.

However, the horror at exfoliated cells exhibited by pathologists at the 1928 meetings was not anomalous. The use of cytology in cancer detection before invasion occurred was seriously resisted by most pathologists. Even if the smear technique was capable of such detection, it was believed that pathologists would not have time to review the large number of slides necessary to find a positive case.⁴¹ That is, it was assumed that the emergent specialty of cytology (the study of exfoliated cells) would be absorbed within those departments of pathology where work centred around the study of cells *in situ* – specifically located and usually already 'suspicious' tissue samples surgically removed for biopsy. Cytological analyses, then, would be done in clinical laboratories along with a host of other diagnostic testing. At this time such laboratories were usually associated

with hospitals and large out-patient facilities. Demand for all kinds of testing had expanded dramatically across the century, in both bacteriological and pathological analyses.⁴² Adding cytological analyses to extant facilities seemed particularly overwhelming in that most slides (about 75%) were expected to be 'normal'.⁴³

But in 1945, a tremendous boost was given to the Pap smear by the newly renamed and profoundly reorganized American Cancer Society (ACS). The original American Society for the Control of Cancer, begun in 1913, 'had been founded by several gynecologists and public-spirited laymen who wanted to impress women with the danger signs of uterine cancer, in an effort to treat cancer before it became advanced'.⁴⁴ By 1943, their activities included a 'Women's Field Army' of 350,000 volunteers, who focused on patient education and awareness.⁴⁵

The new ACS emerged from 1944–46, when a group of business people oriented to fund-raising and research eased out the old guard. This occurred at the same time as the National Cancer Institute (NCI) was being revitalized by the US Public Health Service, and the National Institutes of Health were shifting from 'a nice quiet place out here in the country' to major biomedical research shops.⁴⁶ In 1943, the ACS had an annual budget of \$102,000; by 1945, it was over \$4m and rising.⁴⁷ The focus of the new ACS was on finding a cure for cancer (a 'downstream' approach) rather than cancer prevention (an 'upstream' approach). In terms of direct action, the ACS slogan was 'Every Doctor's Office a Cancer Detection Center'.⁴⁸ The Pap smear appealed to ACS leaders as a simple technique that could help fulfil their slogan without the need for elaborate or expensive new technologies – the right tool for the chosen job.

Fully 25% of the new ACS funds were destined for research, with Dr Charles Cameron serving as medical and scientific director. Cameron promptly became a major advocate of the Pap smear as a core focus for ACS research, cancer prevention and early intervention.⁴⁹ Via Cameron's advocacy, the ACS sponsored the First National Cytology Conference in Boston in 1948, a turning point in the wider acceptance of the Pap smear as a cancer screening procedure. Because the ACS was supporting the smear, pathologists and others, hoping to share in the newfound largesse of the ACS and its close ally the NCI, also began to support it.⁵⁰

Training in reading slides, promotion of the smear as a screening technology, and major disease incidence discovery studies were the next foci, followed by more and bigger conferences. Beginning in 1947, Papanicolaou had regularly offered training courses in cytology at Cornell Medical School, for pathologists and others.⁵¹ Arthur Holleb was asked by Cameron to 'travel round the country and sell this to pathologists and gynecologists',⁵² which he did with some success. In the 1950s, the ACS and the NCI initiated large-scale Pap smear screening studies including, for example, one study of 95,000 women in Memphis.⁵³ At the First International Cancer Cytology Congress, Papanicolaou summed up developments as follows:

I feel that I should not close this discussion without mentioning the decided impetus given to exfoliative cytology by the encouragement, sanction and financial support of such organizations as the American Cancer Society, the National Cancer Institute of the US Public Health Service and many local agencies interested in cancer research and control. This meeting, which has brought into close association such important societies as the American Society of Clinical Pathologists, the College of American Pathologists, the Inter-Society Cytology Council and the International Union Against Cancer in a program centering on cancer cytology should in itself be looked upon as an historical event. With such a spirit of unity we may look forward confidently to greater advancements in this and other related fields that may ultimately lead to the control and elimination of this ruthless disease.⁵⁴

Papanicolaou's career continued apace, with the extension of exfoliative cytology to other organs (such as spinal, lung and breast fluids), and he received several major awards.⁵⁵

Use of the Pap smear as a cancer screening procedure has continued to expand ever since.⁵⁶ It has served as a fundamental and apparently 'scientific' offering in the movement for annual check-ups within obstetrics and gynecology, as these specialties sought to offer functional as well as surgical solutions to women's health problems after World War II. It became part of the 'office visit', normalizing routine medical care. Today, as specialists are moving into primary care, internists are seeking knowledge of how to do Pap smears along with how to prescribe contraception.⁵⁷ In sum, the Pap smear was a technology that 'fit' with the early intervention (rather than prevention) goals of major actors in the cancer arena, the ACS and the NCI, which certainly enrolled it and Papanicolaou as allies, and promoted them relentlessly for many years.

The 'Wrong' Tool for the Job?: Criteria for Constructing 'Rightness'

We began by noting that an ideal public health screening test is fast, cheap and accurate. That the Pap smear was or is any of these has always been highly contentious. In 1956, Emerson Day stated:

The basic characteristic of a screening procedure is that it is used in groups of presumably healthy persons to identify those individuals who are in need of further diagnostic attention. It may be applied to members of a community or to selected individuals where, for special reasons, there is an increased risk of disease. . . . To be useful as a public health or clinical measure, a screening procedure must meet certain criteria:

- (1) The procedure must be relatively simple both at the clinical and at the laboratory level. Its performance must require a minimum of time and effort on the part of the doctor or technician, and it must be simple enough to be acceptable to the asymptomatic patient. At the laboratory or reading end, it must not be costly or present great technical difficulties.
- (2) The yield of findings must be commensurate with the effort expended.

- (3) The results obtained by a screening procedure do not have to meet the highest level of diagnostic accuracy but must meet certain standards of reproducibility and reliability.⁵⁸

While, in 1956, Day thought the Pap smear was the 'outstanding success' of exfoliative cytology, it remains arguable as to whether any of these criteria were actually being met.⁵⁹ Despite over 30 years of its use, recent studies have still been able to point to major problems with the Pap smear, in terms of the criteria cited by Day. Further, for pathologists the Pap smear was anything but successful as a screening tool, regardless of its effectiveness.

We next discuss the three major criteria for determining why the Pap smear is *not* a good screening test, and may be constructed as a 'wrong' tool: chronic ambiguities as to when or what is cancer; chronic ambiguities in classification systems for Pap smears; and chronic ambiguities in reading the slides and placing them into those classification systems. These and other problems collectively result in a *false negative rate* of between 15% and 40%, or even up to 50%.⁶⁰ That is, cancers and precancerous conditions are not 'caught in the screen' at those percentages. It is not our argument that these more recent studies are more reliable than earlier studies or judgements about the success of the Pap smear.⁶¹ Our point is that it has always been possible to define the Pap smear as a 'suitable' screening technology, or to define it as 'not suitable'. Our purpose here is to open up the question of how this procedure, which performed with such ambiguity even when measured against the agreed-upon criteria of the time, became a stabilized and widespread routine cancer-screening approach. In other words, we address how, given that the Pap smear could just as easily be represented as the wrong tool for the job, its characterization as the right tool for the job came to prevail, and has been maintained. Let us now discuss the three criteria used to evaluate the Pap smear.

Chronic Ambiguities About When is Cancer

One fundamental element that makes the Pap smear less effective is chronic ambiguity regarding cervical abnormalities, which leads to the question of *when or what is cancer*. Chronic constructions of physiological and molecular ambiguity on this question are due to the fact that such cellular changes can take place to the point of invasion and then (1) regress to 'normal'; or (2) remain relatively static in a 'non-normal state'; or (3) progress to invasive cancer. Further, while we know that about one in ten supposed 'precancerous' lesions will progress to invasive cancer if left untreated,⁶² there is no reliable means of predicting which ones. Recently, genetic analyses have attempted to distinguish between reversible atypia and true neoplasia,⁶³ and linkages have been established between certain strains of the Human Papilloma Virus and invasiveness,⁶⁴ but there is no conclusive means of prediction, even today. Even superficial consensus among clinicians on when cancer exists has proven elusive. In short, the

when and what of cancer are contingent and defined through concrete practices.

Chronic Ambiguities of Classification

Constructions of cancer via the Pap smear are achieved through the use of a Pap smear classification system. The Pap smear as a screening device is intended as a mechanism of triage, and its classification systems have been designed with this more or less in mind. We have discussed classification systems in greater detail elsewhere; our major interest here is in pointing to such systems as sites of ambiguity and contestation.⁶⁵

Figure 1 shows the major classification systems in use, in chronological order of their development.⁶⁶ Note the different criteria embedded within each system. In the words of a recent account:

To do a Pap smear, a doctor or nurse scrapes away some cells from the cervix and walls of the vagina, affixing them to a glass slide and sending the slide to a cytology laboratory for analysis. There it is read by a technician, or cytotechnologist, most often a female college graduate with one year of training, who must scan each of the 50,000 to 300,000 cells on the slide, looking for abnormalities in cell shape, size or number. Those slides containing abnormalities are then sent to a pathologist for review.⁶⁷

Each slide is then reported to the health care practitioner in terms of a classification system or systems (some laboratories use more than one). Medical action is usually predicated upon the placement of the smear within a classificatory system, and triage ensues: 'inadequate' smears (not enough cells of the right types) must be repeated; 'normal' smears are generally reported to patients; and 'clearly cancerous' smears are reported to patients who are referred for treatment. It is 'abnormal' (but not clearly cancerous) smears which are the particular sites of much contestation, especially in terms of the construction of classificatory systems *per se*, and of the placement of smears within them. Of course, there is also controversy over what should happen next in terms of treatment and/or active monitoring.⁶⁸

Comparing the classificatory systems in Figure 1, the first major point to note is the way in which classification processes have expanded over time to embrace non-invasive conditions (which might be benign or precancerous, but are usually indeterminate). Second, if we examine the chart carefully, we see that across time there were three, four, five, seven, six, and then again five classes or categories. Thus a pattern of increasing complexification was followed by one of simplification. This occurred over a period when the Pap smear was more and more widely used as a screening tool, increasingly institutionalized, and increasingly assessed for its adequacy and cost-effectiveness as an indicator for active prevention or early intervention.⁶⁹ Most laboratories now report using more than one of these systems, a practice which generates its own set of constraints and confusion.⁷⁰ Rather than representing global standardization (a stated goal

FIGURE 1
Comparison of Cervical Cancer Classification Systems

Martzlloff c. 1923		Grade I		Grade II	Grade III	Fat Spindle Cell Type
Broders c. 1926		Grade I		Grade II	Grade III	Grade IV
Pap & Traut c. 1948	Class I	Class II	Class III	Class IV	Class V	
Dysplasia c. 1953	Benign	Atypia	Mild DYSPLASIA	Severe DYSPLASIA	Invasive Cancer	
CIN c. 1970	Benign	Atypia	CIN I	CIN II	CIN III	Invasive Cancer
Bethesda/SIL c. 1988	Benign	Atypia	Low-Grade SIL	High-grade SIL	Squamous Cell Carcinoma	

in this arena), the existence of divergent classification systems illustrated in Figure 1 shows instead some of the heterogeneity requiring local 'work-arounds' and 'tinkering' at many levels.

Slowness and Ambiguity in Reading and Processing Slides

The third area of chronic ambiguity, which can certainly slow down the pace, is reading and processing the slides.⁷¹ As one of the major actors in the field recently noted:

Any person who has not screened a large number of cervicovaginal smears has a limited notion of the physical and mental effort the procedure requires. To do it well, every cell in the smear must be viewed, and any abnormality must be recorded on the slide. . . . Even for a very well-trained and talented cytotechnologist this is a time consuming task. A careful reading of a Pap smear requires at least five minutes per slide . . . and a difficult case sometimes requires considerably more time.⁷²

One of Papanicolaou's junior colleagues recalled that Papanicolaou himself, who by then had been reading slides for at least 25 years, said he spent over half an hour each on difficult slides.⁷³

Further, one cannot always read slides 'on demand'. In the words of one of the major women in laboratory medicine, Ruth Graham, who in 1956 wrote extensively on the laboratory organization of cytotechnology:

It is assumed that she [the technician] has screened the entire slide and, furthermore, that in screening she has actually a visual impression of what she has seen. This last statement may sound somewhat redundant. I assure you, it is not. It is only too easy to rapidly move to the mechanical stage and to be thinking of something else and never really *see* any of the cells. This happens to everyone, but the responsible technician will recognize that it is happening, do something else for a little while, and then return to microscopic work.⁷⁴

This quotation illustrates the difficult technical nature of cytological screening, and how easy it is to lose one's concentration when performing such detailed work. The distinctive attribute of cytology – that it examines free-floating exfoliated cells *each of which is unique* – has further implications for slowness and ambiguity in reading slides, and in being trained to read them:

While histologic slides can be cut for hundreds of students, each slide showing the *identical* features of disturbed tissue architecture, the teacher and student in cytology must compare their understanding of isolated cellular features. Mass teaching and even the seminar exercise, in which sets of [identical] slides sent to a group of participants are later discussed in a meeting with a moderator, *are impossible* therefore, because cells stubbornly refuse to display their morphologic features with sufficient uniformity. This immediately shifts the emphasis toward training of individuals by individuals, as in residence and fellowship programs.⁷⁵

This quotation is interesting not only for its discussion of the challenges of cytology, but for its representation of cells as active participants, stubbornly refusing to give up their secrets to the cytotechnician – or even the pathologist.

In sum, then, it seems clear that the Pap smear does not fulfil the criteria of a good screening procedure: it is not always fast, accurate or cheap. Yet this does not necessarily mean that the Pap smear is the ‘wrong’ tool for the job of cervical cancer screening. For some actors, the Pap smear *qua* technology did not meet particular clinical and/or research needs, and thus never became a tool at all. For other actors, however, the meaning of the Pap smear shifted from technology developed in one context to a useful tool in other contexts. However, addressing the Pap smear’s shortcomings in terms of the criteria listed above, and then transforming it into a workable tool, required more than simply attributing a different meaning to this technology. In order to work as the right tool for the job of cervical cancer screening, the Pap smear had to become embedded in work arrangements, and in the technological arena in which it was used. In short, it had to be *made into* a tool that would work well enough for the purposes at hand.

Making (and Remaking) the Pap Smear Into the ‘Right’ Tool for the Job

Over the past half century, several sets of concrete practices have been used to achieve ‘rightness of fit’ between the Pap smear ‘tool’ and the ‘job’ of cancer screening. While these practices certainly have been deliberate strategies of cytologists, pathologists and other actors, they may also be seen as contingent developments related to the Pap smear’s entrenchment locally. That is, some of these practices had very local origins and then spread; while others were essentially national from their inception. Further, not all practices recur at all sites. These practices have included, within the cancer arena, gendering the division of labour, automating the division of labour, cost juggling, abandoning global claims of classificatory accuracy for local negotiated orders, and promotion of alternatives to the Pap smear. From outside the cancer arena, particularly from women’s health groups, have come pressures to rate and regulate laboratories.

Gendering the Division of Labour in Cytological Screening

Gendering the division of labour – using lower-paid women workers wherever possible – has been a major strategy for making the Pap smear into the right tool. This can be viewed as the feminization of the often hidden occupation of technician,⁷⁶ and was also reflected in Papanicolaou’s early research on the smear in women. There were eight major workers in that endeavour: Papanicolaou, Hashime Murayama (artist), Drs Herbert Traut and Andrew Marchetti, three paid women technicians (Charlotte Street, Alberta Kuder and Huldah Boerker), and one volunteer technical

assistant (Mary G. Mavroyeni Papanicolaou [known as 'Mrs Pap'], who served in the laboratory for many years).⁷⁷

In the 1950s, as the Pap smear became a more common screening device, and laboratories had to reorganize to address this work in bulk, many found that 'the major shortcoming of cancer cytology at present is the gross inadequacy of laboratory facilities for reliable cytological services, both screening and diagnostic'.⁷⁸ One proposed solution to this problem was 'a substantial increase in the number of technicians trained in screening and of pathologists experienced in cytodagnosis'. Given a ready supply of personnel, Day argued that there must be laboratory facilities available throughout the country in which trained personnel could work. Such an effort, he proposed, would 'probably require the aggressive support of such organizations as the American Cancer Society and the National Cancer Institute, and the guidance of a body such as the Inter-Society Cytology Council'.⁷⁹

With respect to staffing the laboratories, Day believed that screening and interpreting smears was the 'proper function' of trained cytotechnicians. While potentially invading the professional arena of pathologists, he argued, 'this is the only way in which screening cytological services can be provided on an adequate volume basis'. In addition, screening by cytotechnicians results in 'an essential saving of professional time in a busy laboratory'.⁸⁰ Thus, Day's solution to what he viewed as the major shortcomings of cancer cytology was a hierarchized laboratory, with technicians who were largely female performing 90% of screenings without the assistance of pathologists, who would be called in only when 'abnormalities' were identified.

Others echoed Day's concerns, and raised additional doubts about the role of pathologists, mostly men, in cytological practice. For example, Elizabeth McGrew noted:

The need for cytologic service however is immediate and nationwide. If it is to be met adequately it must be met by pathologists now in practice, already overworked, often unable to attend even short meetings because of heavy hospital responsibilities. Full-time, long-term training programs are *out of the question for these men*.⁸¹

The increasing feminization of the job of technician is important here. You may well have noted the gendering of pronouns as we have quoted different physicians. In fact, some very explicit gendering was found in the published literature. In 1956, Ruth Graham took up these issues of laboratory organization:

To begin this discussion, I would like to define the duties of the technician in a cytology laboratory. She is responsible for the preparation and staining of specimens. . . . Her most responsible and exacting duty is the screening of the slides. By screening, it is implied that every field on every slide is examined for any cell which may be either suspicious of malignancy or definitely malignant. If no atypical cells are found, the slide is considered to be negative, *and that negative diagnosis is the entire responsibility of the cytotechnician*.⁸²

The gendered division of labour includes 'personal qualifications' as well:

What qualifications should the cytotechnician have? It has been my experience that her personal qualifications are much more important than her academic achievements. These personal qualifications are first, and most important, a real sense of responsibility, ability to maintain a high standard of attention for rather long intervals of time, and, finally, the visual ability to distinguish fine differences in detail. I am often asked if a cytotechnician should have a BS degree in Science. I feel that it is preferable. In other words, given two candidates with equal personal qualifications, one with and one without a college degree, I should take the girl with a degree. However, as I have said, I regard the personal qualifications as more important than the academic ones. The best technician I ever had graduated from high school and had never seen a microscope until she volunteered in our laboratory.⁸³

These personal qualifications vividly echo those specified for domestic servants, as does the routine surveillance of their activities and character.⁸⁴ Comparatively, it is interesting to read this same woman's description of the qualifications of cytologists, usually male:

These [qualities], admittedly, are much more difficult to define than those of the cytotechnicians. There are, in this and other countries, clinician-cytologists, pathologist-cytologists, and a very small but, I hope, important group of people whose predominant interest is cytology – the cytologists. How can we state the qualifications for such a diversified group? I think we can. A cytologist is a person of high academic level with a particular interest and special training in cytology. This definition will fit the clinician, the pathologist, and the cytologist.⁸⁵

Here the language is noticeably non-gendered, and other differences among cytologists are well and carefully respected.⁸⁶

The implications for women of a gendered division of labour in the Pap smear arena include low pay for difficult work which offered, in 1956 as now, the worst combination of high responsibility with low or no autonomy, job dissatisfaction arising from repetition and boredom, problems with eye strain, and exploitation of women, especially where this work has over the past decade been converted into a cottage industry – home-based labour paid on a piece-work basis.⁸⁷ In short, these are technological sweatshops of late capitalism.

In recent years, there has been considerable controversy (even reported in the *Wall Street Journal*) around laboratory screening practices, which has prompted attempts at a major reorganization. In the mid-1980s, in response to a flurry of reports about questionable laboratory practices, Congress began investigating Pap smear laboratories. At that time, there were no mandatory federal guidelines regarding cytotechnician training or Pap smear analysis. Much of the controversy centred around the legality of 'Pap mills' – laboratories that offered bargain rates for interpretation of slides.⁸⁸ 'Pap mills' rates are significantly lower than other laboratories' because their technicians often read 200 or more slides per day, ignoring the American Society of Cytotechnology's recommendation that they read

no more than 90 slides per day.⁸⁹ Further, because compensation is on a piece-work basis, technicians are encouraged to speed up their work or take slides home with them for analysis. All of these factors resulted in significantly increased false-negative rates and misdiagnoses, in a number of cases with fatal consequences for women patients.⁹⁰

Following its investigation, Congress implemented new federal regulations for Pap smear testing, including laboratory guidelines.⁹¹ However, these have faced major opposition from pathologists and cytotechnologists, represented by powerful professional organizations.⁹² Lost in this debate are the voices of the mostly female cytotechnicians employed in Pap smear laboratories. Today there are serious laboratory shortages among medical technicians, including cytotechnicians.⁹³ In fact, in 1990, 'cytotechnician' was listed as one of *Working Woman Magazine's* ten worst jobs for women. The article cited low pay, stress and the 'burden of making life and death decisions'.⁹⁴ For these reasons among others, as women can find employment elsewhere, they rapidly do so.

In addition to changes in female cytotechnicians' roles in the division of labour, there has also been a gendered reorganization in the Pap smear arena around *who* actually does the screening. The vast majority of providers now taking Pap smears are non-physician practitioners such as nurses, nurse practitioners and nurse midwives, most of whom are women.⁹⁵ These dynamics reflect the gender, race and class layers of the US health care system more broadly.⁹⁶ Moreover, nurses and nurse practitioners are increasingly gaining expertise with other technologies in the Pap arena, including colposcopy and cervicography.⁹⁷

Automating the Division of Labour in Cytological Screening

Almost since the first moment Pap smears were used for mass screening, efforts have been made to automate various aspects of the process, to speed them up and cut costs. Automation was a strategy that could be deployed either in conjunction with gendering the division of labour, or as an alternative. In 1956, Day argued that automation was a key part of the enhancement of laboratory facilities needed to reduce the shortcomings of cancer cytology, 'of vital importance in enabling us to extend cytologic services to large segments of the population'.⁹⁸ We have constructed three rough categories of automation activities: automated reading of Pap smears *per se*; automation of various aspects of cytology-related laboratory work (for instance, data storage); and combinations of these.

Automation was a principal focus of the 1968 Conference on Early Cervical Neoplasia. Myron Melamed and Louis Kamentsky believed that an effective automated screening device should possess the following criteria: the ability to examine cells individually; the correlation of measurements with light microscopy (which was the only technique available for identifying human cancer cells); the ability to display results in a usable manner; the capability of examining cells rapidly; and last but not at all least, compatibility with current methods of collecting cell samples.⁹⁹ In

short, they outlined the basic requirements for making the Pap smear 'the right tool for the job' through automation of a number of important steps in the screening process. What is particularly (and sociologically) distinctive about their criteria is that they reflect how deeply the Pap smear was already, by 1969, entrenched locally, nationally and internationally, with both clinical and public health goals. That is, within 20 years of the general introduction of the Pap smear, a fundamental criterion of 'good' Pap smear automation was that it would not totally disrupt extant working arrangements and commitments.

Automating the screening process was but one strategy for mechanizing the division of labour. Another strategy focused on automation of cell classification. As George Wied, Peter Bartels and Gunter Bahr argued:

There are several advantages to teaching a computer to identify and classify cells. The first is that one obtains objective data in numerical form. Second, a computer-made decision can be made on cells which show the identifying data patterns in a marginal form only. . . . Finally, the practically unlimited storage capacity of the computer provides the possibility of charting the clinical course of a disease in terms of the patients' changing cell pattern. This approach is likely to obtain important prognostic significance.¹⁰⁰

This quotation reflects classic technological claims-making strategies¹⁰¹ among cytologists and others, circa 1968. Yet over the years it became clear that the problems of automating slide reading were quite recalcitrant, and just over 20 years later (in 1989), the AMA Council on Scientific Affairs stated:

The examination of cells is a subjective procedure dependent on the skill and expertise of the observer as well as the time devoted to reviewing the slide. As such, it is fallible. To date, there are no practical methods of automating or standardizing this test in a way analogous to, for example, clinical chemistry.¹⁰²

In the meantime, during the late 1960s, biomedical laboratories also entered the computer age, automating other aspects of Pap-related laboratory work, especially record-keeping. Wied and his colleagues raved:

The application of computers to clinical cytology and cell research is an inevitable development. It will not replace anybody or put anybody current[ly] in cytopathology or cytotechnology out of a job. However, it will provide better medical care, improved service at a lower cost, provide data which were unobtainable before, and revolutionize our cytological laboratory procedures during the next decade.¹⁰³

Those were the early dreams. The same authors also tempered their enthusiasm with a dose of sociological analysis:

The computer industry seems to have difficulties grasping the intricacies, complexities, and magnitude of the data processing needs of a medical laboratory. . . . It is a common complaint that the cytopathologist-user and

the electronics engineer-designer propose different ways of solving problems. A communication gap exists between the one who works with the biologic sample and the one who designs the computer hardware.¹⁰⁴

Despite such now classic problems, these authors, in 1968, modelled the automated laboratory as others had done before them.¹⁰⁵ In the 1970s, the NCI jumped into the computing fray with its own programme to automate cytology, echoing many earlier efforts and strategies.¹⁰⁶ Various models of computerized data storage and retrieval have since been constructed to automate more and more aspects of laboratory practice – with the exception of smear reading, which has remained recalcitrant to automation efforts.¹⁰⁷ In part, this is because automation efforts have attempted to mechanize the *subjectivity* involved in reading the notoriously ambiguous Pap smears.

A quarter of a century later, goals for automated scanners have not been met, despite many efforts. Yet there may be possibilities on the horizon. According to a recent report, the FDA is considering approval of the Papnet system designed to ‘double-check’ Pap smears that have already been read by a cytotechnician.¹⁰⁸ This new technology is claimed to increase the detection rate in the 50 million Pap smears performed annually in the USA. Using computer technology developed to detect missiles in the so-called Star Wars defense initiative, Papnet works by selecting the 128 most abnormal-looking cells in a smear, and greatly enlarging them for additional analysis. In addition to this effort to automate the screening itself, Vicky Singleton and Mike Michael chronicle efforts to automate and centralize the UK Cervical Screening Programme through computerized patient call and recall systems. The purpose of this automation is to ‘prevent women “slipping through the net”’.¹⁰⁹

Juggling Costs

The third set of practices we discuss is cost juggling, or laboratories simply charging more for other tests to keep the charges they make for Pap smear readings down. This strategy has been a hidden phenomenon, little discussed in the literature. Laboratories that process Pap smears also typically undertake many other tests in laboratory medicine, including pathological and histological tests. As an earlier quotation noted, there has been considerable success in automating tests based on clinical chemistry. This has occurred in a typical pattern of development: the means of automation were developed; prototypes and early models were very costly; as kinks were worked out and mass production and means of systematic integration developed, costs decreased rapidly. Laboratories had initially charged very high prices for these new tests, reflecting their actual cost. However, rather than decrease charges proportionally as costs decreased, laboratories have had the alternative of keeping costs for certain tests high when they cannot charge ‘real time and money’ costs for another test, due to competition, tradition and/or profit margin goals.

In interviews with people in laboratory medicine, this strategy of cost juggling was described as fundamental to keeping the cost of Pap smears down, making it *appear* to fulfil the criterion of ‘cheap’ within the ‘fast, cheap and accurate’ troika of criteria for mass screening procedures. This mechanism works especially well in conjunction with a gendered division of labour, and the concomitant development of smear reading as a home-based cottage industry with payment on a piece-work basis, both of which reduce costs. However, it is these practices which have also been linked to high rates of false negatives for Pap smears, as high as 15–40% or more,¹¹⁰ due in part to haste in reading slides.

Abandoning Global Accuracy for Locally Negotiated Orders

Another major strategy for making the Pap smear the right tool for the job of cancer screening has been the abandonment of hopes for global accuracy or accord about classification of Pap smears, in favour of local working arrangements between clinicians and pathologists in the actual laboratories where their work is done. Once controlled clinical trials were applied to Pap smear screening practices, many studies documented the lack of accord across laboratories, cytologists and cytotechnicians in the placement of smears along classification systems. While the ends of the continuum tend to be clear, classifying in the middle is notoriously varied and contested. The search for means of standardization has been long, arduous and not particularly successful.¹¹¹

Yet, in contrast, it has been recognized informally for some time that local arrangements between particular clinicians and laboratories can achieve a much higher degree of smear-reading accord, through regular communication about particular smears and about patient outcomes (biopsies, surgeries, and the like) over time. We are calling these *locally negotiated orders* to emphasize the on-going nature of the interactions, and hence the ever-present possibility of change.¹¹² While never demonstrating 100% classificatory accord, such local negotiations or work-arounds seem to generate better than average results, especially in clinical outcomes. In fact, these informally recognized locally negotiated orders have recently become one premise for a new classification system, the Bethesda system.¹¹³ Even those who oppose the Bethesda system on other grounds laud such locally negotiated orders: ‘The Bethesda group also appropriately emphasized the importance of close communication between the cytopathologist and the clinician’.¹¹⁴

Further, locally negotiated orders are stressed in current clinician training programmes, as practitioners are encouraged to ‘Call your cytologist’, ‘Choose your lab carefully’, ‘Develop a relationship’, and ‘Work together’.¹¹⁵ We suspect that it is now, and has been for some years, the high quality of locally negotiated orders in analyzing ambiguous Pap smears that has been most influential in *maintaining* the Pap smear as an effective screening procedure.¹¹⁶ Right tools are not uniform across contexts, despite goals of global standardization which assume that they are.

Their rightness is contingent and specific to local work arrangements and practices, and must be routinely performed, as our account has shown.

Exploring Alternatives and/or Adjuncts to Pap Smear Screening

Last, replacing or supplementing the Pap smear as a diagnostic technology has also been favoured by some who believe it cannot really be made into the right tool for the job of *screening*, regardless of the multiple kinds of tinkering strategies delineated here. Some alternative diagnostic procedures which have been promoted and tested include colposcopy, cervicography, cryotherapy, laser therapy, LEEP (Loop Electrosurgical Excision Procedure), ViraPap (a Human Papilloma Virus DNA Detection Kit) and speculscopy. A key advantage of many of these techniques is that they combine diagnosis with treatment. However, most of these technologies have been found to be much too expensive for mass screening, while diagnostic accuracy remains problematic.¹¹⁷ They also illustrate some of the tensions between clinical and public health contexts, each of which may have differing goals and commitments.

Of potential concern to women's health groups, a 'do-it-yourself Pap smear', called My-Pap, allows a woman to collect cellular material from her vagina and cervix using a douche, rather than a scraping technique, and then to send the sample to a laboratory for analysis. Although this innovation would probably be fast, cheap, simple and private, it is not necessarily accurate. In a clinical trial of 1151 cases, My-Pap and the standard Pap smear showed similar diagnostic effectiveness at the higher end of the abnormality spectrum; however, My-Pap was not as sensitive at lower levels of cellular abnormality.¹¹⁸ It is also unclear whether women using My-Pap would be able to obtain appropriate follow-up services in the event of an abnormal laboratory report, and this was among the reasons why the US FDA did not approve this technology.

In short, alternatives to the clinic-based Pap smear, like the smear itself, are also not fast, cheap and accurate, and hence do not fulfill the criteria for a good screening technology. Further, they are not already organizationally embedded, which makes the Pap smear a consistently welcome diagnostic intervention in both clinical and public health contexts.

Attempting to Rate and Regulate Laboratories

Most of the 'tinkering' strategies discussed here have been pursued, or in fact led, by medical professionals of some sort. In sharp contrast, major scandals about the quality of smears, especially concerning high false negative rates, emerged from consumer concerns and led to women's health movement, consumer movement, and public health department activism. This activism has been aimed at both assuring and expanding federal regulation of diagnostic laboratories. Such regulation is made possible, in the USA, by federal funding for Medicaid and, through grants,

for various sites of the provision of family planning services (which tends to be primary gynecological care, including Pap smears). In both such situations, the federal government can make laboratory certification requisite for reimbursement. (Block grants to states can eliminate such requirements.)

While activism has assumed varied forms in varied places, one of the earliest alarms raised by consumers was in San Francisco in the mid-1970s. There the Coalition for the Medical Rights of Women, an emergent activist group, took up the problem of very high rates of erroneous smear reading at a local laboratory.¹¹⁹ The subgroup in the organization focusing on this work pursued this problem and, realizing from their research that it was generic rather than just an isolated local issue, published a booklet for women's health groups and other health care providers all over the USA and beyond. Titled 'Choosing a Pap Smear Lab', the booklet gave detailed advice on assessing laboratory quality and reliability, and on intervening where smear reading was cavalier.¹²⁰

Concern about the adequacy of smear reading was also echoed in the training sessions provided by public health departments for lay health care providers, nurses and physicians. One such session, in California in 1982, was titled 'Secrets Your Pap Smear Never Told You'.¹²¹ Because public health departments actually paid for the reading of Pap smears, they could actively and formally intervene in the assignment of at least their own contracts for smear reading. Informally, word of mouth travels fast, and clinicians certainly do not want to (be seen to) patronize laboratories with poor track records.

By 1984, concern about laboratories was expressed in the third edition of the major women's health movement book, retitled *The New Our Bodies, Ourselves*.¹²² In 1987, further scandal about Pap smears hit the mainstream media, as the *Wall Street Journal*, *Newsweek*, *Washington's Insider Focus*, and even television news programmes carried a number of exposés about laboratory tests, focusing on Pap smears in particular.¹²³ High false negative rates resulting in personal tragedies, oppressive working conditions for cytotechnologists, high profit margins for poor quality work, unregulated 'Pap mill' laboratories with inadequately trained and unlicensed staff, and the very efficacy of the smear as an indicator, were all called into question by the intensive media coverage. Most of these have been concerns regarding the smear since the 1940s. Certain laboratory regulations are now in place, and it seems quite likely that the ascendant women's health movement (or at least the much less radical Women's Health Initiative) should sustain these concerns for some time.¹²⁴

In short, consumers, the women's health movement and public health activists together have successfully tinkered with some of the most blatant abuses for financial gain in the Pap smear arena, targeting laboratories with inadequate smear-reading practices. Even those outside the usual boundaries of the network, or those in the arena as implicated actors (for example, consumers), can tinker with and reshape elements of the arena.

Discussion

We have presented a portrait of the Pap smear's historical technological embeddedness within laboratory infrastructures, across half a century. Our account, grounded in a social worlds/arenas framework, challenges the notion of 'system' or 'network' by emphasizing the multiplicity of perspectives of actors and their social worlds, and the non-systematic aspects of interaction, such as tinkering and locally negotiated orders in the Pap smear arena.¹²⁵ In concluding, we suggest that making the Pap smear the 'right' tool for the job actually depends on one's conception of what precisely 'the job' is. That is, different criteria would obtain for cyto-technicians, pathologists, clinicians, epidemiologists, patients, the American Cancer Society, the National Cancer Institute, women consumers/patients and other interested and/or implicated actors.

For whom, then, was the Pap smear the 'right' tool? Importantly, it was the right tool for the American Cancer Society, as it sought to transform itself from a lay patient education organization into a major biomedical research sponsor, rapidly developing the organizational infrastructure for implementation of mass screening programmes with NCI. It was clearly right for George Papanicolaou as he imported cytological work from zoology into medicine, and applied it first to reproductive endocrinological research and then to one of the most pressing medical problems of his and our time – cancer. It was the right tool for a new *medical* cytology *vis-à-vis* pathology, because cytology offers the possibility of early clinical intervention without prior indicators of disease, and without invasive and expensive surgical procedures. It would also seem to have been the right tool for thousands (if not millions) of women patients in whom (pre)cancer was detected and successfully treated. However, it was not a particularly right tool for women laboratory technicians 'enrolled' in underpaid and disabling cottage industry sweatshops, nor for women diagnosed with false negatives for whom treatment was too late or never triggered by the Pap smear as a method for screening. Neither was the smear the right tool for women diagnosed with false positives, which could (and often did) cause needless anxiety and intervention.

In short, the Pap smear served as a symbol of the 'new' cancer research, and offered a 'cheap' means of importing prevention and early intervention into routine clinical practice. But definition as the 'right' tool did not necessarily mean that the Pap smear became stabilized, once and for all, as a diagnostic technology. Once embedded in practice, the rightness of the Pap smear has had to be continually negotiated, maintained and restored via the multiple tinkering strategies discussed here: gendering and automating the division of labour, juggling costs, focusing on local negotiations for clinical treatment decision-making, attempting to regulate laboratories, and exploring alternative and/or adjunct technologies. Thus, the 'rightness' of a tool may be constantly constructed and reconstructed in diverse ways, at multiple levels of social organization, by actors with a multiplicity of perspectives, operating in complicated social worlds, with

diverse interests and agendas, which may all be varyingly addressed over time. Radically, the tool may never be stable or more than 'satisfactory'. As we were preparing the final draft of this paper, an editorial was published titled, 'The Elusive Unequivocal Pap Smear'.¹²⁶

How, then, does a tool that is neither particularly 'right' nor 'wrong' endure at the heart of an arena for half a century? First, it must be 'good enough' at least minimally to satisfy all of the social worlds in that arena. Second, it must do important work for the actors and/or worlds with the most power and resources. And third, it must to some degree be standardized and stabilized, however wobbly. That the Pap smear has become the most widely used screening technology reflects, in part, the increasing importance of public health versus local clinical goals. We have discussed the strategies pursued by many different actors working at many different levels of intervention to achieve this degree of 'good enough', and *for whom*.

Many in science and technology studies have argued that ongoing processes of standardization add stability and resilience. Alberto Cambrosio and Peter Keating have illustrated this in immunology, and Joan Fujimura in molecular biology.¹²⁷ Usually it is the technologies – the tools – which are standardized and stabilized. However, although the Pap smear was particularly resistant to standardization and stabilization *per se*, the laboratory around it was less so. There the main category of workers was standardized – female cytotechnicians were paid as little as possible. The record keeping was standardized – where computing technologies have contributed most. And the costs were standardized – by cost-shifting within the laboratory.

Thus, while the Pap smear resists standardization, in terms of global accord in interpretation, stability was achieved by other means, by at least the possibility of somewhat stable locally negotiated orders. We would also argue that some degree of stability around the extant tool – the Pap smear – was further guaranteed by 50 years of sustained effort at finding a better tool, in automating the reading or replacing the smear with another technology. Hope, if not hype, satisfies some groups' agendas.

Our findings here are remarkably similar to those of the actor-network analysis of the contemporary UK Cervical Screening Programme by Vicky Singleton and Mike Michael.¹²⁸ They suggest that the 'ambivalence' of actors/actants about the roles of self and others in the network of cancer screening can actually reinforce and sustain the network. By making such instabilities permanent parts of the network, heterogeneity along a number of different planes can render the network durable, because actors can occupy both the margins and the core. They can be *both* critics and supporters of the network, both insiders and outsiders, loci of patterns of support and resistances. Yet, in Singleton and Michael's account, does the network hold? By emphasizing contingency and ambivalence, especially among clinicians, they point to precisely the elements we have stressed in our account: interaction, negotiation and meaning-making at local sites.

How is this to be understood *vis-à-vis* actor-network theory and social worlds/arenas theory? Clearly, in neither account is the scientist or the executive followed. Singleton and Michael followed General Practitioners and the UK Programme, and we followed most everyone and everything. Nor is the technology standardized and hence stabilizing. Nor are the needs and goals of the actors and social worlds involved in accord: rather, they conflicted. Singleton and Michael call this ‘ambivalence’, viewing their contribution as friendly amendments to actor-network theory:

The alternative metaphor might be that of permanent reform; the world we wish to examine is one of inherent instability and incessant skirmishes.¹²⁹

We would agree and go further, including interpretive struggles, outright conflict and power relations. Symmetry is a good first step. We would use it thus to assure that all the actors are present and accounted for. But here too we need to push further, and add implicated actors who, in actor-network terms, may not be present at the beginning with much agency at all, but who may be the focus of key projects in the arena. They may make their presence felt later, as did consumers, women’s health and public health activists in our story.

In conclusion, we highlight the remaining elusiveness of *interesement* in actor-network theory, and counter from an alternative position of social worlds/arenas theory. Taking all the actors very, very seriously can have exceptional analytic payoffs – even where agency may be initially invisible to (or ignored by) other actors. Specifying who or what is present (or at least implicated) in the situation at all times can be especially important in analyzing change. Social worlds and arenas may be very unstable places, and stability may cohere in surprising ways. Certain social worlds can be flexible rather than brittle, continually manoeuvring for advantage, while others can be recalcitrant. The rewards of flexibility are supposedly high. But weak ties can become strong; weak actors can too, as the initially more powerful lose their edge. Both may be much more robust than appearances indicate.¹³⁰

Notes

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Meetings of the Society for Social Studies of Science (Cambridge, MA, 1991), and of the American Sociological Association (Pittsburgh, PA, 1992).

1. For a more recent framing of a 'good' screening procedure, see S.J. McPhee, R.J. Richard and S.N. Solkowitz, 'Performance of Cancer Screening in a University Internal Medicine Practice', *Journal of General Internal Medicine*, Vol. 1, No. 5 (September/October 1986), 275–81. Policy around screening is becoming increasingly contested as cost/benefit analyses in the health field become increasingly fine tuned; see, for example, Louise B. Russell, *Educated Guesses: Making Policy About Medical Screening Tests* (Berkeley, CA: University of California Press, 1994); Jane E. Brody, 'Nationwide Tests Set for Prostate Cancer, But Doubts Surface', *New York Times* (20 September 1992), B4; Gina Kolata, 'New Ability to Find Earliest Cancers: A Mixed Blessing?', *New York Times* (8 November 1994), B5–6; Leopold G. Koss, 'The Papanicolaou Test for Cervical Cancer Detection: A Triumph and a Tragedy', *Journal of the American Medical Association*, Vol. 261, No. 5 (3 February 1989), 737–43. For an analysis of the early development of the Pap smear, see the paper by Elise S. L'Esperance, which is particularly detailed about the construction of risk in relation to screening: 'Early Diagnosis of Cancer', *Bulletin of the New York Academy of Medicine*, Vol. 23 (1947), 394–409, esp. 397–98.
2. For a fuller discussion of tools in scientific and medical practice, particularly the simultaneous construction of 'right', 'tools' and 'job', see Adele E. Clarke and Joan H. Fujimura (eds), *The Right Tools for the Job: At Work in Twentieth-Century Life Sciences* (Princeton, NJ: Princeton University Press, 1992; Paris: Synthelabo Press, 1996).
3. Karin Knorr-Cetina, *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science* (Oxford: Pergamon Press, 1981).
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6. See, for example, Kenneth E. Studer and Daryl E. Chubin, *The Cancer Mission: Social Contexts of Biomedical Research* (Beverly Hills, CA: Sage, 1980); James T. Patterson, *The Dread Disease: Cancer and Modern American Culture* (Cambridge, MA: Harvard University Press, 1987); Robert F. Bud, 'Strategy in American Cancer Research After World War II: A Case Study', *Social Studies of Science*, Vol. 8, No. 4 (November 1978), 425–59; and Samuel S. Epstein, *The Politics of Cancer* (New York: Anchor, 1979).
7. To offer another example, the arena/domain of national and international family planning/population control has been extremely contested for most of the 20th century. Emerging from this contestation is a strong perspective, on the part of women from many countries who are actors in this domain, that 'the medium is the message'. That is, the means of delivery of any contraceptive(s) is itself the technology; in concrete practice, it is part and parcel of, and indistinguishable from, the contraceptive. See Ruth Dixon-Mueller, *Population Policy and Women's Rights: Transforming Reproductive Choice* (New York: Praeger, 1993). On the concept of arena/domain, see Adele E. Clarke, 'Social Worlds/Arenas Theory as Organizational Theory', in David Maines (ed.), *Social Organization and Social Process: Essays in Honor of Anselm L. Strauss* (Hawthorne, NY: Aldine de Gruyter, 1991), 119–58.
8. See Vicky Singleton and Mike Michael, 'Actor-Networks and Ambivalence: General Practitioners in the UK Cervical Screening Programme', *Social Studies of Science*, Vol. 23, No. 2 (May 1993), 227–64; Singleton, 'Stabilizing Instabilities: The Role of the Laboratory in the United Kingdom Cervical Screening Programme', in Marc Berg and Annemarie Mol (eds), *Differences in Medicine: Unravelling Practices, Techniques, and Bodies* (Durham, NC: Duke University Press, forthcoming).

9. In anthropological terms, collective social actors/social worlds are subcultures. Elsewhere we link interpretive flexibility to distinctively local practices in the use of particular Pap smear classification systems – how local practices can ‘work around’ sustained conflicts of interest. We also foreground conflict and render the concept of closure problematic, asking ‘Whose closure is it anyway, and who is prepared to do something about it?’. See Adele E. Clarke and Monica J. Casper, ‘From Simple Technology to Complex Arena: Classification of Pap Smears, 1917–1990’, in Casper and Barbara Koenig (eds), Special Issue on ‘Biomedical Technologies’, *Medical Anthropology Quarterly*, Vol. 10, No. 4 (December 1997), 601–23. On the non-human, see Latour, *op. cit.* note 5. For other exemplars of social worlds/arenas analysis, see Adele E. Clarke and Theresa Montini, ‘The Many Faces of RU486: Tales of Situated Knowledges and Technological Contestations’, *Science, Technology, & Human Values*, Vol. 18, No. 1 (Winter 1993), 42–78; Clarke, ‘A Social Worlds Research Adventure: The Case of Reproductive Science’, in Susan E. Cozzens and Thomas F. Gieryn (eds), *Theories of Science in Society* (Bloomington, IN: Indiana University Press, 1990), 23–50. For theoretical development, see Clarke, *op. cit.* note 7; Anselm L. Strauss, ‘A Social Worlds Perspective’, *Studies in Symbolic Interaction*, Vol. 1 (1978), 119–28; Strauss, *Creating Sociological Awareness: Collective Images and Symbolic Representation* (New Brunswick, NJ: Transaction, 1991); and Strauss, *Continual Permutation of Action* (New York: Aldine de Gruyter, 1993).
10. The ‘executive approach’ is described in S. Leigh Star, ‘Power, Technologies and the Phenomenology of Conventions: On Being Allergic to Onions’, in John Law (ed.), *A Sociology of Monsters: Essays on Power, Technology and Domination* (London: Routledge, 1991), 26–56. Had we taken ‘the executive approach’ and followed the technoscientist here, Papanicolaou would have ended up constructed as a much more major figure than we believe he was. This is the bias of the executive approach. See also Joan H. Fujimura, ‘Crafting Science: Standardized Packages, Boundary Objects and “Translation”’, in Andrew Pickering (ed.), *Science as Practice and Culture* (Chicago, IL: The University of Chicago Press, 1992), 168–211.
11. In the interests of full disclosure, we note that we both get our Pap smears fairly regularly. Sometimes the implicated actors are us. On implicated actors generally, see Clarke & Montini, *op. cit.* note 9. On researchers as implicated when studying controversy, see Pam Scott, Evelleen Richards and Brian Martin, ‘Captives of Controversy: The Myth of the Neutral Social Researcher in Contemporary Scientific Controversies’, *Science, Technology, & Human Values*, Vol. 15, No. 4 (Autumn 1990), 474–94; Adele E. Clarke, ‘Controversy and the Development of Reproductive Sciences’, *Social Problems*, Vol. 37, No. 1 (February 1990), 18–37; Monica J. Casper, ‘Reframing and Grounding “Non-Human” Agency: What Makes a Fetus an Agent?’, *American Behavioral Scientist*, Vol. 37, No. 6 (May 1994), 839–56; and Fujimura, *op. cit.* note 10. For an extended discussion of this and related issues, see also Malcolm Ashmore and Evelleen Richards (eds), Special Issue on ‘The Politics of SSK: Neutrality, Commitment and Beyond’, *Social Studies of Science*, Vol. 26, No. 2 (May 1996), 219–468.
12. A National Institutes of Health panel recently concluded that ‘in theory, cervical cancer is a cancer that we can completely prevent. . . . If we could reach all the women in this country who are not getting regular Pap tests we could eradicate this type of cancer’. The report found that about half of the women diagnosed with cervical cancer in the USA have never had a Pap test, and it also concluded that most cervical cancer is related to infection by the Human Papilloma Virus (HPV), which is sexually transmitted. See ‘Pap Tests, Safe Sex Could Eradicate Cervical Cancer, Experts Conclude’, *Sacramento Bee* (4 April 1996), A10; on the HPV link, see *op. cit.* note 63, below. See also ‘Older Women Need Pap Test, Study Says’, *Sacramento Bee* (7 June 1995), A4.
13. See Ralph M. Richart and Thomas C. Wright, Jr, ‘Controversies in the Management of Low-Grade Cervical Intraepithelial Neoplasia’, *Cancer*, Vol. 71, No. 4 (15 February 1993), 1413–21.

14. See Koss, op. cit. note 1; Claudia Baquet and Knut Ringen, 'Health Policy: Gaps in Access, Delivery, and Utilization of the Pap Smear in the United States', *Milbank Memorial Fund Quarterly*, Vol. 65, Suppl. 2 (1987), 322–47; and Deborah Norton, 'From Confusion to Clarity: Applying the New Bethesda System', paper presented at the Tenth Annual EPA OB/GYNE Update (San Francisco, CA, 25 October 1991). See also Linda C. Harlan, Amy Bernstein and Larry Kessler, 'Cervical Cancer Screening: Who is Not Screened and Why?', *American Journal of Public Health*, Vol. 81 (1991), 885–90.
15. See Clarke & Fujimura (eds), op. cit. note 2. The actors we have studied do not necessarily, and in fact rarely, explicitly share our theoretical assumptions.
16. See Naomi Aronson, 'Science as a Claims-Making Activity: Implications for Social Problems Research', in Joseph W. Schneider and John I. Kitsuse (eds), *Studies in the Sociology of Social Problems* (Norwood, NJ: Ablex, 1984), 1–30. Thanks to one of our anonymous reviewers for the point about deployment of artifacts.
17. Monica J. Casper and Marc Berg, 'Introduction: Constructivist Perspectives on Medical Work: Medical Practices and Science and Technology Studies', *Science, Technology, & Human Values*, Vol. 20, No. 4 (Autumn 1995), 395–407, make similar points about the relevance of medicine to technoscience studies.
18. Thanks to one of our anonymous reviewers for this phrasing about recolonization of the women's health movement. See also Sheryl Burt Ruzek, 'Medical Response to Women's Health Activities: Conflict, Accommodation, and Cooptation', *Research in the Sociology of Health Care*, Vol. 1 (1980), 335–54, and Vicky Singleton's 'Feminism, Sociology of Scientific Knowledge and Postmodernism: Politics, Theory and Me', in Ashmore & Richards (eds), op. cit. note 11, 445–68. Authors and audiences alike must negotiate the roiling straits between the Scylla of constructionism and the Charybdis of materialism, just like in 'real' life. Practically – in practice – when studying, writing and presenting work on medical technologies, one often feels like a lightning conductor. The intensity of many people's practical concerns always threatens to rupture the theoretical discussion period after a presentation. Certainly women in our audiences are often particularly riveted, but many male partners of women diagnosed with cervical abnormalities have also interrogated us as key resources for their practical/private lives.
19. Thanks to one of our anonymous reviewers for reminding us of this.
20. Studer & Chubin, op. cit. note 6; Bud, op. cit. note 6; Patterson, op. cit. note 6; Joan H. Fujimura, 'Ecologies of Action: Recombining Genes, Molecularizing Cancer, and Transforming Biology', in Susan Leigh Star (ed.), *Ecologies of Knowledge: New Directions in the Sociology of Science and Technology* (Albany, NY: SUNY Press, 1995), 302–46; and Fujimura, *Crafting Science: A Socio-History of the Quest for the Genetics of Cancer* (Cambridge, MA: Harvard University Press, 1996).
21. In summing up the discussion at a meeting of the CIBA Study Group No. 3 (8 May 1959), the chairman stated: 'I believe that in view of the accessibility of this primary organ, the cervix, we will be the first to make a major contribution to the solution of the problem of cancer'; W.C.W. Nixon, 'Chairman's Closing Remarks', in CIBA Foundation (ed. G.E.W. Wolstenholme & Maeve O'Connor), *Cancer of the Cervix: Diagnosis of Early Forms* (London: J. & A. Churchill; Boston, MA: Little, Brown, 1959), 110. See also George N. Papanicolaou, 'Historical Development of Cytology as a Tool in Clinical Medicine and in Cancer Diagnosis', *Acta Unio Internationalis Contra Cancrum*, Vol. 14, No. 4 (1958), 249–54.
22. Adele E. Clarke, *Disciplining Reproduction: Modernity, American Life Sciences, and the 'Problem' of Sex* (Berkeley, CA: University of California Press, 1998); Nelly Oudshoorn, 'On the Making of Sex Hormones: Research Materials and the Production of Knowledge', *Social Studies of Science*, Vol. 20, No. 1 (February 1990), 5–33; and Oudshoorn, *Beyond the Natural Body: An Archaeology of Sex Hormones* (London: Routledge, 1994).
23. Koss, op. cit. note 1, 737.

24. Walter S. Ross, *Crusade: The Official History of the American Cancer Society* (New York: Arbor House, 1987), 76. For additional background information on women's cancer, Valerie Fildes, Lara Marks and Hilary Marland (eds), *Women and Children First: International Maternal and Infant Welfare* (New York: Routledge, 1992).
25. Sam Gordon Berkow, 'A Visit with Dr George N. Papanicolaou', *Obstetrics and Gynecology*, Vol. 16 (1960), 243–52.
26. For discussion of the Pap smear in the reproductive sciences, see Adele E. Clarke, 'Embryology and the Development of American Reproductive Sciences, 1910–1945', in Ronald Rainger, Keith Benson and Jane Maienschein (eds), *The American Expansion of Biology* (New Brunswick, NJ: Rutgers University Press, 1991), 107–32; and Clarke, op. cit. note 22. Guy Marrian called the years circa 1926–40 'the heroic age' (see Alan S. Parkes, 'The Rise of Reproductive Physiology, 1926–1940: The Dale Lecture for 1965', *Journal of Endocrinology*, Vol. 34, No. 4 [March 1966], xx–xxxii, quote at xx), while Alan Parkes termed it 'the endocrinological gold rush' (see A.S. Parkes, 'Prospect and Retrospect in the Physiology of Reproduction', *British Medical Journal* [1962], Vol. 2 [14 July], 71–75, quote at 72). One reason for this explosion of reproductive science was that Papanicolaou presented his work at the meetings of the American Society of Anatomists, which was the scholarly home of most of the outstanding American reproductive scientists: 'For years the meetings of the anatomical society were actually dominated by reports of work with this new technic' [*sic*] (Berkow, op. cit. note 25, 247). See also Diana Long, 'Physiological Identity of American Sex Researchers Between the Two World Wars', in Gerald L. Geison (ed.), *Physiology in the American Context, 1850–1940* (Bethesda, MD: American Physiological Society, 1987), 263–78.
27. The chronicle of the Committee for Research on Problems of Sex documents that Papanicolaou worked on grants provided through Dr Charles Stockard as key investigator from 1923 to 39, and then, after Stockard's death, had grants in his own name from 1939 to 41. These publications focused on comparative oestrus, endocrinological impacts on the vaginal smear, reproduction in the guinea pig, and technical concerns (for example, staining of smears); see Sophie Aberle and George W. Corner, *Twenty-Five Years of Sex Research: The National Research Council's Committee for Research on Problems of Sex, 1922–1947* (Philadelphia, PA: W.B. Saunders, 1953), 198, 216–18. It seems very likely, from several sources, that these projects were predominantly those of Papanicolaou; see especially Erskine Carmichael, *The Pap Smear: Life of George N. Papanicolaou* (Springfield, IL: Charles C. Thomas, 1973), 63.
28. See Aurel Babés, 'Diagnostic du cancer du col uterin par les frottis' ('Method for the Diagnosis of Uterine Cervical Carcinoma by Means of the Smears'), *La Presse Médicale*, Vol. 36 (11 April 1928), 451–54; George L. Wied, 'Pap-Test or Babés Method?', *Acta Cytologica*, Vol. 8 (1964), 173–74; and Larry E. Douglas, 'A Further Comment on the Contributions of Aurel Babés to Cytology and Pathology', *ibid.*, Vol. 11 (1967), 217. Among those who pursue primacy in science, Babés is considered a 'co-discoverer' of exfoliative cytology for cancer diagnosis.
29. Philip J. Pauly, 'Essay Review: The Eugenics Industry – Growth or Restructuring?', *Journal of the History of Biology*, Vol. 26 (1993), 131–45.
30. Andrew A. Marchetti, 'Biographic and Personal Recollections of George N. Papanicolaou', *Obstetrical and Gynecological Survey*, Vol. 24, No. 7 (July 1969), 680–84, at 682. (This was the first paper delivered at the American Cancer Society's Conference on Early Cervical Neoplasia [Cherry Hill, NJ: Cherry Hill Inn, 11–13 September 1968], the Proceedings of which take up the whole issue [*ibid.*, 679–1048].) For Papanicolaou's original paper, see G.N. Papanicolaou, 'New Cancer Diagnosis', *Proceedings of the Third Race Betterment Conference* (Battle Creek, MI: Race Betterment Foundation, 1928), 528–34.
31. Heinz Grunze and Arthur I. Spriggs (eds), *History of Clinical Cytology: A Selection of Documents* (Darmstadt, FRG: G-I-T Verlag Ernst Giebel, 1983), 88.

32. Papanicolaou, op. cit. note 21. For related problems with cervical staining techniques, see Harold Speert, *Essays in Eponymy: Obstetric and Gynecologic Milestones* (New York: Macmillan, 1958), 285–95.
33. Carmichael, op. cit. note 27, 68.
34. In 1942, Traut became Chair of Obstetrics and Gynecology at the UCSF Medical School, continuing his collaboration from afar; see Marchetti, op. cit. note 30, 682; Steven R. Long and Michael B. Cohen, 'Classics in Cytology 4: Traut and the Pap Smear', *Acta Cytologica*, Vol. 35 (1991), 140–42.
35. Carmichael, op. cit. note 27, 69.
36. George N. Papanicolaou, 'A New Procedure for Staining Vaginal Smears', *Science*, Vol. 95 (24 April 1942), 438–39.
37. George N. Papanicolaou and Herbert F. Traut, 'The Diagnostic Value of Vaginal Smears in Carcinoma of the Uterus', *American Journal of Obstetrics and Gynecology*, Vol. 42 (August 1941), 193–206.
38. Carmichael, op. cit. note 27, 71.
39. The Commonwealth Fund sponsored a volume on maternal mortality focused largely on childbirth, and was involved in a major epidemiological study of this problem in New York City; see Iago Galdston, *Maternal Deaths: The Way to Prevention* (New York: Commonwealth Fund, 1937). See also Fildes, Marks & Marland (eds), op. cit. note 24.
40. Carmichael, op. cit. note 27, 73 (emphasis added). In 1943, Papanicolaou and Traut's first major monograph appeared, entitled *Diagnosis of Uterine Cancer by the Vaginal Smear*, also sponsored by the Commonwealth Fund. The second monograph, which Papanicolaou said should have come first, was *The Epithelia of Women's Reproductive Organs*, published in 1948. Papanicolaou's *Atlas of Exfoliative Cytology* appeared in 1954, designated the 'Bible' of cytologists, and earning him the honour of being 'the father of cytology'; Marchetti, op. cit. note 30, 682.
41. Carmichael, op. cit. note 27, 75.
42. See, for example, Patricia Peck Gossell, 'A Need for Standard Methods: The Case of American Bacteriology', in Clarke & Fujimura (eds), op. cit. note 2, 287–311; James R. Wright, Jr, 'The Development of the Frozen Section Technique, the Evolution of Surgical Biopsy, and the Origins of Surgical Pathology', *Bulletin of the History of Medicine*, Vol. 59 (1985), 295–326; and Wright, 'The 1917 New York Biopsy Controversy: A Question of Surgical Incision and the Promotion of Metastases', *ibid.*, Vol. 62 (1988), 546–62.
43. George L. Wied, Peter H. Bartels and Gunter F. Bahr, 'Laboratory Organization in the Detection and Diagnosis of Early Cervical Neoplasia', *Obstetrical and Gynecological Survey*, Vol. 24, No. 7 (July 1969), 935–66.
44. Charles Cameron, quoted in Lester Breslow, *History of Cancer Control in the US, 1946–1971* (Washington, DC: National Cancer Institute, 1978), Appendix 5.
45. Patterson, op. cit. note 6, 171.
46. *Ibid.*
47. *Ibid.*, 171–73.
48. *Ibid.*, 174.
49. Ross, op. cit. note 23, 84.
50. For a fuller account of ACS activities, see Charles S. Cameron, 'Recruitment of Personnel in Cytology', *Transactions of the First International Cancer Cytology Congress* (Chicago, IL: Drake Hotel, 8–11 October 1956), 5–6, and a long interview with Cameron in Breslow, op. cit. note 44, Appendix 5. (These *Transactions* were not, to our knowledge, ever published: we have access to a mimeo version in the UCSF Library.) On the politics of cancer in the USA generally, see Epstein, op. cit. note 6; Patterson, op. cit. note 6; and Studer & Chubin, op. cit. note 6.
51. Seventy participants, 45 of them pathologists, attended Papanicolaou's first course, which fit smoothly with the overall plan Papanicolaou and Hinsley had originally developed for dissemination of the Pap smear: see Carmichael, op. cit. note 27, 76.
52. Ross, op. cit. note 23, 86.

53. Carmichael, op. cit. note 27, 83. For more detailed accounts of those studies, see Rodney B. Nelson and Albert W. Hilberg, 'The Diagnosis of Unsuspected Cancer of Cervix', *Journal of the National Cancer Institute*, Vol. 11 (June 1951), 1081–91; and Herbert F. Sandmire, Stephen D. Austin and Richard C. Bechtel, 'Experience With 40,000 Papanicolaou Smears', *Obstetrics and Gynecology*, Vol. 48, No. 1 (July 1976), 56–60.
54. George N. Papanicolaou, 'Historical Landmarks in Exfoliative Cytology', *Transactions*, op. cit. note 50, 93–99, at 99.
55. 'Carcinoma of the vagina, cervix, endometrium and fallopian tube had been diagnosed through vaginal and uterine aspiration smears. Application of the smear technique for cancer detection also had been extended to urine, sputum, gastric washings, ascites, prostate secretions, spinal fluid, and breast secretions': see Carmichael, op. cit. note 27, 78. Papanicolaou received the Lasker Award of the American Public Health Association in 1950; see Berkow, op. cit. note 25, 252, for his other honours. Despite having founded a successful new specialty, exfoliative cytology, he did not receive a Nobel Prize.
56. It is precisely the question of who – which segments of a population – has Pap smears that is the epidemiological/public health question at this historical point. If smears are done in a population segment, they are usually followed via triage with appropriate services including prevention/early intervention. Both within the USA and elsewhere, especially where there is no national health service, poorer women who have impaired access to all medical care and/or impaired care are much less likely to have Pap smears and appropriate triage services, and therefore to have higher cervical cancer rates. The current exception in the USA is African-American women, who are screened at rates equal to or higher than white women: see, for example, Harlan, Bernstein & Kessler, op. cit. note 14; Centers for Disease Control, 'Black-White Differences in Cervical Cancer Mortality: United States, 1980–1987', *Morbidity and Mortality Weekly Report*, Vol. 39 (1990), 245–48; and J. Mandelblatt *et al.*, 'Breast and Cervical Cancer Screening of Poor, Black Women: Clinical Results and Implications. Harlem Study Team', *American Journal of Preventative Medicine*, Vol. 9, No. 3 (May/June 1993), 133–38. See also Sue Fisher and Ann L. Page, 'Women and Preventive Health Care: An Exploratory Study of the Use of Pap Smears in a Potentially High-Risk Appalachian Population', *Women and Health*, Vol. 11 (1986), 83–100.
57. Clarke, op. cit. note 22, and Jenny Ross, MD, personal communication (20 November 1993).
58. Emerson Day, 'Accomplishments and Shortcomings of Cancer Cytology', *Annals of the New York Academy of Sciences*, Vol. 63 (30 March 1956), 1070–78, at 1070.
59. Helen I. Mariesskind, *Women in the Health System: Patients, Providers, and Programs* (St Louis, MO: C.V. Mosby, 1980).
60. Jerome H. Gundersen, Charles W. Schauburger and Nancy R. Rowe, 'The Papanicolaou Smear and the Cervigram: A Preliminary Report', *Journal of Reproductive Medicine*, Vol. 33 (1988), 46–48; Norton, op. cit. note 14.
61. J. Robb, 'The Pap Smear is a Cancer Screening Test – Why Not Put the Screening Error Rate in the Report?', *Diagnostic Cytopathology*, Vol. 9, No. 5 (October 1993), 485–86; Leopold G. Koss, 'Cervical (Pap) Smear – New Directions', *Cancer*, Vol. 71, No. 4 (15 February 1993), 1406–12; and Nancy Volkens, 'Problems and Progress with Pap Smear Screening Reviewed', *Journal of the National Cancer Institute*, Vol. 84, No. 22 (18 November 1992), 1694–95.
62. Koss, op. cit. note 1, 740.
63. The nuclear DNA of lesions which remained static or eventually progressed to invasive carcinoma had an aneuploid distribution, while most (but not all) of those which regressed to 'normal' had a diploid or polyploid pattern. See Ekkehard Grundmann and E. Pedersen (eds), *Cancer Registry* (Berlin: Springer-Verlag, 1975), and Richart & Wright, op. cit. note 13.
64. Linkages between cervical cancer and the Human Papilloma Virus are claimed to indicate that this type of cancer may be sexually transmitted: see, for example, Robert

- J. Kurman *et al.*, 'Papilloma Viruses and Cervical Neoplasia', in Peter M. Howley and Thomas R. Broker (eds), *Papilloma Viruses: Molecular and Clinical Aspects* (New York: Allan F. Liss, 1985), 3–18; Koss, *op. cit.* note 1, 740; Mark H. Schiffman *et al.*, 'Epidemiologic Evidence Showing that Human Papillomavirus Infection Causes Most Cervical Intraepithelial Neoplasia', *Journal of the National Cancer Institute*, Vol. 85, No. 12 (16 June 1993), 958–64; Gloria Y. Ho *et al.*, 'Persistent Genital Human Papillomavirus Infection as a Risk Factor for Persistent Cervical Dysplasia', *ibid.*, Vol. 87, No. 18 (20 September 1995), 1365–71; Richart & Wright, *op. cit.* note 13; Richard A. Cone and Kevin J. Whalley, 'Monoclonal Antibodies for Reproductive Health: Part I. Preventing Sexual Transmission of Disease and Pregnancy with Topically Applied Antibodies', *American Journal of Reproductive Immunology*, Vol. 32 (1994), 114–31; and 'Researchers Link Cervical Cancer, Viruses', *Sacramento Bee* (7 June 1995), A4. However, despite the proven effectiveness of actual prevention of sexually transmitted diseases from HPV and CIN to AIDS, barrier means of contraception (such as the diaphragm and condoms) are not actively promoted. See A.L. Coker *et al.*, 'Barrier Methods of Contraception and Cervical Intraepithelial Neoplasia', *Contraception*, Vol. 45, No. 1 (January 1992), 1–10.
65. Clarke & Casper, *op. cit.* note 9.
66. Dr Eileen King, an internationally renowned cytologist, reviewed this comparative chart and found it a reasonable portrayal.
67. Robin Marantz Henig, 'Is the Pap Test Valid?', *New York Times Magazine* (28 May 1989), 37–38.
68. See Richart & Wright, *op. cit.* note 13.
69. Several major policy analyses have taken up these issues. See Anne-Marie Foltz and Jennifer L. Kelsey, 'The Annual Pap Test: A Dubious Policy Success', *Milbank Memorial Fund Quarterly*, Vol. 56, No. 4 (Fall 1978), 426–62; Baquet & Ringen, *op. cit.* note 14; and Koss, *op. cit.* note 1.
70. See, for example, Richart & Wright, *op. cit.* note 13; National Cancer Institute, 'Bethesda System for Reporting Cervical/Vaginal Cytologic Diagnoses: Revised After the Second Cancer Institute Workshop, April 29–30, 1991', *Acta Cytologica*, Vol. 37 (1993), 115–24; P.T. Valente, 'Update on the Bethesda System for Reporting Cervical/Vaginal Diagnoses', *Cancer Treatment and Research*, Vol. 70 (1994), 15–28; and D.G. Ferris *et al.*, 'Physician Attitudes Toward the Bethesda System of Reporting Cervical Cytology', *Family Practice Research Journal*, Vol. 13, No. 3 (September 1993), 267–73.
71. The same holds for reading biopsies. As a histologist stated in 1956: 'In order to distinguish lesions of this kind morphologically, a great amount of experience is required in many cases. It must, however, also be admitted that a definite evaluation of changes in the epithelium based on histological criteria is not possible in every case, and the personal attitude of the investigator will often be decisive in reaching final diagnosis'; *Transactions*, *op. cit.* note 50, 88.
72. Koss, *op. cit.* note 1, 738.
73. Marchetti, *op. cit.* note 30, 68.
74. Ruth M. Graham, 'Operation of a Training Center for Cytology', *Transactions*, *op. cit.* note 50, 61–64, at 61 (emphasis in original); Eileen B. King, 'Operation of a University Cytology Center', *ibid.*, 67–68. One of the earliest training centres was established at the University of California, San Francisco, by Herbert Traut and John T. Frost: see Long & Cohen, *op. cit.* note 34, 141.
75. Elizabeth A. McGrew, 'Operation of Training Workshops in Cytology', *Transactions*, *op. cit.* note 50, 65–66, at 65 (second emphasis added).
76. See, for example, Anselm L. Strauss, Leonard Schatzman, Rue Bucher, Danuta Erlich and Mel Sabshin, *Psychiatric Ideologies and Institutions* (Glencoe, IL: Free Press, 1964), 228–61; Bucher, 'On the Natural History of Health Care Occupations', *Work and Occupations*, Vol. 15 (1988), 131–47; Bonnie Bullough and Vern Bullough, 'Sex Discrimination in Health Care', *Nursing Outlook*, Vol. 23, No. 1 (January 1975), 40–45; and Steven Shapin, 'The Invisible Technician', *American Scientist*, Vol. 77 (1989), 553–63.

77. Marchetti, op. cit. note 30, 681–82; George N. Papanicolaou and Herbert F. Traut, *Diagnosis of Uterine Cancer by the Vaginal Smear* (New York: The Commonwealth Fund, 1943).
78. Day, op. cit. note 58, 1076.
79. Ibid.
80. Ibid.
81. McGrew, op. cit. note 75, 65 (emphasis added).
82. Graham, op. cit. note 74, 61 (emphasis added). Discussion went as follows:

Question: ‘Ruth Graham, John McDonald, and myself and others found that high school graduates who had no previous experience with microscopy can be made into excellent technicians. Why make college graduates trainees? Won’t that decrease the number available?’

Answer: ‘I, too, have had the experience that individuals from high school very often proved to be the most capable workers in not only cytology but other fields of laboratory medicine as well. I think it is unfortunate that we have no established means of recognizing these people. However, in order to establish reasonably sound criteria which will apply to the greater number of workers, you must start some place to establish minimal requirements, and the ones that I described today were essentially those that were worked out by the special committee of the Inter-Society Cytology Council.’

Quoted in A. Reynolds Crane, ‘Certification of Personnel Engaged in Cytology’, *Transactions*, op. cit. note 50, 69–74, at 73.

83. Graham, op. cit. note 74, 61–62.
84. Mary Romero, *Maid in the USA* (New York: Routledge, 1992).
85. Graham, op. cit. note 74, 62–63.
86. AMA Council on Scientific Affairs, ‘Quality Assurance in Cervical Cytology: The Papanicolaou Smear’, *Journal of the American Medical Association*, Vol. 262, No. 12 (22/29 September 1989), 1672–79, described the current composition of cytopathology laboratory personnel and requisite educational standards as follows: ‘In larger-volume cytopathology laboratories, initial cytological interpretation is performed by cytotechnologists . . . all atypical, unsatisfactory, or abnormal smears are routinely referred to a supervisor or cytopathologist. . . . After a 1-year training program, the cytotechnologist is expected to identify and discriminate between normal and pathological processes in cytological preparations. . . . As of August 1988, all cytotechnologists must possess a baccalaureate degree before taking the Board of Registry examination. Unfortunately, not all cytology laboratories are required to employ registered or trained cytotechnologists’. The Council also argued that laboratories must employ enough cytotechnologists to handle the volume of cases, and detailed the workload: ‘The initial evaluation of gynecologic smears is both physically and mentally demanding, and the cytotechnologist must not be pressured to exceed his or her capabilities’ (ibid., 1675–76).
87. In early 1996, a Milwaukee laboratory was fined the maximum penalty for ‘reckless homicide’ in the deaths of two women whose Pap smears had been misread by the lab. The women’s tests were sent by an HMO to Chem-Bio and handled by the same technician, who was paid on a piece-work basis, and was reading ‘several times as many Pap smears as recommended by professional guidelines’; see Associated Press, ‘Lab Fined \$20,000 in 2 Deaths – Patients’ Pap Smears Misread’, *Sacramento Bee* (23 February 1996), A10.
88. Walt Bogdanich, ‘Doubts About the Pap Smear’, *Wall Street Journal* (11 December 1987), 4–6.
89. Mary McNamara, ‘Pap Smears: Testing the Tests’, *Ms.* (April 1988), 65–67.
90. Singleton & Michael, op. cit. note 8, discuss a similar situation in the UK, in which laboratories in the UK Cervical Screening Programme were scrutinized over high error rates in screening.

91. On federal regulations, see Hugh M. Shingleton *et al.*, 'The Current Status of the Papanicolaou Smear', *Ca: A Cancer Journal for Clinicians*, Vol. 45, No. 5 (September/October 1995), 305–20.
92. 'Angry Cytotechs Respond to Misrepresentation', *ASCP News* (August 1990), 3.
93. Eileen King, MD, personal communication (8 July 1991).
94. Quoted in *ASCP News*, *op. cit.* note 92.
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