vaccination as well as the use of international smallpox vaccination certificates. Vaccination was a long-established procedure, however, and it was unlikely to be discontinued unless both health officials and the public were aware of what had been accomplished and had confidence in that achievement. A public information officer, Mr James Magee, was therefore recruited to work full time with the Smallpox Eradication unit in Geneva.

Accounts of the progress made in the Intensified Programme appeared regularly in newspapers and magazines around the world, documentary films were made by the public broadcasting service in the USA and by Japanese television, and many countries issued special stamps; commemorative medals were also struck. Eventually, the press coverage became sufficiently extensive to cause one correspondent to write in *Science* (Wade, 1980) that "WHO has found numerous occasions on which to announce the eradication of smallpox. Another such announcement, issued with some new degree of bureaucratic solemnity, is due to emerge on 12 May. Experts consider that only definitive action by the Nobel Peace Prize committee can break the chain of transmission". However, despite numerous newspaper and magazine articles in countries throughout the world and in publications as diverse as *World health, National geographic, Reader's digest*, the *Encyclopaedia Britannica* and *Scientific American*, many persons of wide reading suggested to smallpox eradication staff that the achievement was too little known and that more should have been written about it.

INTERNATIONAL SUPPORT IN CASH AND IN KIND

One of the most difficult problems was that of ensuring adequate international support for the national programmes, whose needs changed, often substantially, from year to year. In the original plan presented by the Director-General to the Nineteenth World Health Assembly in 1966, four sources of support were envisaged: (1) the WHO regular budget which, in 1967, included US$2.4 million specifically earmarked for smallpox eradication; (2) contributions to the WHO Voluntary Fund for Health Promotion, Special Account for Smallpox Eradication, which the donor could make either in cash or in kind and which, if desired, could be assigned to a specific project or country; (3) bilateral contributions; and (4) contributions from other international agencies.

The Director-General's report to the Nineteenth World Health Assembly (World Health Organization, 1966b) had forecast a need for US$48.5 million in international assistance for a 10-year programme (1967–1976), of which one-third was expected to be provided by the WHO regular budget, the balance having to be obtained from the other sources. Ultimately, international assistance from 1967 to 1979, when eradication was certified, amounted to some US$98 million, of which US$34 million came from the WHO regular budget.

Of the expected sources of support, funds from the WHO regular budget were of particular importance because they could be used wherever required and for any appropriate purpose, including personnel and travel costs, the purchase of supplies and equipment, and local operational expenses—e.g., for petrol, vehicle repairs and living allowances for national staff. These funds served to complement voluntary contributions and national resources, which sometimes provided only partial support for a country programme. In programmes in western and central Africa, for example, national governments paid staff salaries and the USA provided all other needed resources except funds for the purchase of petrol and for vehicle repairs. Comparatively small sums from the WHO regular budget for "local costs", as they were termed, enabled governments in this region to undertake eradication programmes.

Undesignated gifts of cash to the WHO Special Account for Smallpox Eradication could likewise be used for any necessary purpose and had the further advantage that balances could be carried forward from year to year. Few undesignated gifts of cash were received, however, the contributions until 1974 being primarily in the form of vaccine. During the period 1974–1978, several donors made substantial cash contributions to the voluntary fund, almost all of which were designated for use in specific countries.

Significant bilateral support was provided by the USA and the USSR, the former providing almost all international assistance for programmes in western and central Africa, and the latter supplying very large quantities of vaccine to several Asian countries and to

some in Africa. International agencies other than WHO had been expected to provide substantial assistance but little was received.

Except for the first 2 years of the Intensified Programme (1967–1968), when activities in many countries were only just beginning, the inadequacy of resources presented a continuing problem. Headquarters, regional and national staff expended considerable time and effort in attempts to obtain assistance. Frequently, however, it was found that the available funds were sufficient to sustain activities for only a few months. The difficulties, even as late as 1975, may be illustrated by an estimate prepared in July of that year of the requirements and availability of resources for 1975 and the 2 subsequent years in addition to those provided under WHO's regular budget (Table 10.3).

It had been hoped that, when it became apparent that global eradication was feasible and perhaps within reach, funds would be more readily forthcoming. Even during 1976, however, with known smallpox confined to Ethiopia, the problem did not diminish, as is shown by a memorandum of 17 February 1976 from Henderson to the Director of the WHO Regional Office for the Eastern Mediterranean:

"I concur entirely with you in regard to your appraisal of need for a WHO epidemiologist to be attached to the smallpox eradication programmes in Sudan and Somalia ... I fear that there may be unknown foci ... which may yet cause real problems ... However, I'm very concerned about our funding position ... Frankly, at this time, we simply don't have the money to fund the Ethiopian programme beyond April or May and, at the same time, funds for Bangladesh will be exhausted at the end of March. One would have expected all sorts of support at this time but we are simply not getting it."

The WHO Regular Budget

Funds from the WHO regular budget were an important component of international assistance but it was difficult to apply them optimally in the context of ever-changing global needs. Their allocation by WHO Region and by country should ideally have taken into account both relative need and the global strategy, but this was difficult given WHO's decentralized structure and administrative procedures.

The WHO budget process was best suited to the support of a diverse array of national projects, which were usually small and had financial requirements that were reasonably predictable from year to year. The Director-General's annual budget, developed over a 2-year period, was a composite of proposals prepared separately by regional directors and Headquarters units and based, in part, on requests for assistance received from countries. Each regional director drew up a detailed budget specifying personnel and other costs for each project in each country and in the regional office. These project proposals were usually not reviewed by the relevant technical units at Headquarters, which similarly submitted detailed budget proposals of their own, broken down by permanent staff and consultant costs, as well as proposed expenditures for travel, meetings and other items. Following a review of the proposals by the Director-General and the assistant directors-general, an overall proposed programme and budget for the entire Organization was set out in detail for consideration by the Executive Board at its January session and by the World Health Assembly, which was usually convened in May—7 months before the beginning of the next financial year. The Smallpox Eradication unit had no indication as to the total allocations available for smallpox eradication each year until the budget volume was distributed.

Table 10.3. Estimated requirements and available resources as at July 1975, in addition to those provided under the WHO regular budget, 1975–1977 (US$)

Year	Amount needed	Available	Deficit
1975	1 975 000	1 445 000	530 000
1976	1 560 000	345 000	1 215 000
1977	1 450 000	345 000	1 105 000

The budget was almost invariably approved by the Health Assembly as presented, after which each regional director could transfer WHO regional resources from one project to another as need and opportunity presented. Funds could be transferred from one region to another only by the Director-General, but such transfers were seldom made.

In 1967, more than 90% of all the funds voted for smallpox eradication by the Health Assembly were allocated by the Director-General to the 4 regions in which endemic smallpox was then present (Table

10.4), only a small amount (about 8%) being provided to support Headquarters or interregional activities.

Because of the nature of the budget process, the Smallpox Eradication unit decided that the best way of achieving the optimum allocation of resources was through close collaborative planning with regional office staff. If this could be achieved, it was believed that a consensus on needs and priorities could be reached which would be reflected in annual budgets, and it would be possible to provide up-to-date information to regional directors so that transfers of funds could be made where required. Thus, each year, a planning meeting was scheduled which was attended by the officer responsible for smallpox eradication in each regional office together with senior Smallpox Eradication unit staff. Although it was usually possible to reach a consensus as to priorities and allocations of resources, the subsequent execution of agreed plans ranged from excellent to indifferent.

During the first 2 years of the Intensified Programme, the full utilization of appropriated funds was a major concern. At the Nineteenth World Health Assembly, in 1966, a number of delegates had proposed a budget of US$1 million for smallpox eradication, since they doubted whether the Organization could fully utilize US$2.4 million. Although the Director-General had assured them that the larger amount could be well used, this was, in fact, not easily accomplished. Before funds could be obligated, country plans and lists of the supplies and equipment needed had to be drawn up. With full-time advisers for smallpox eradication in only 2 of the WHO regions, and those not the most seriously affected, the task was not easy. Yet, if the funds were not fully expended, it would reflect poorly on the Organization. In 1967 and 1968, a lengthy correspondence was carried on with each of the WHO regions concerned, analysing and reanalysing budgets and obligations and repeatedly urging the regions to develop agreements and obligate funds as soon as possible.

The full obligation of allocated funds would have been facilitated by the procurement of a reserve fleet of vehicles, to be dispatched as they became needed by countries. This was a practice followed by UNICEF and one which would have alleviated serious delays in starting programmes, which were often caused by 12–18-month delivery times for vehicles. A proposal to this effect, however, was not accepted.

Table 10.4. Director-General's budgetary allocations for smallpox eradication for 1967 and estimated actual expenditure (US$)

Region	Budget allocations for smallpox	Estimated actual expenditure
Africa	658 428	460 090
Americas	629 000	742 063
South-East Asia	815 030	295 281
Europe	0	0
Eastern Mediterranean	246 706	573 999
Western Pacific	2 000	55 831
Headquarters and interregional	210 640	268 552
Total	2 561 804	2 395 816

In 1967, plans were quickly developed in the Region of the Americas and the Eastern Mediterranean Region but far less was accomplished in Africa and South-East Asia. As the year progressed, it became apparent that the funds committed in these latter regions would fall substantially short of those allocated. This problem, however, was solved in a manner that served indirectly to provide the Smallpox Eradication unit with added discretionary resources for emergency needs. Towards the end of 1967, the Regional Director for South-East Asia was persuaded to release funds allocated for use elsewhere and the Director-General approved the transfer. Some were transferred to the Regions of the Americas and the Eastern Mediterranean and some were used for the purchase of large numbers of the new bifurcated needles and jet injectors. The subsequent ability to dispatch bifurcated needles and jet injectors (as well as vaccine) promptly to countries in need was of great help in carrying out programme activities. The Regional Director for Africa chose not to release his unobligated funds and, in December, at the end of the financial year, they were returned to Headquarters. Fortunately, however, it proved possible to recover them for the programme, thanks to the Division of Budget and Finance. Cash contributions to the WHO Voluntary Fund for Health Promotion's Special Account for Smallpox Eradication had not been large, but a moderate sum had accumulated by 1967. In that year, virtually all these funds had been spent on travel, consultants and training materials. The unobligated funds from the African Region were used to cover these

expenditures, and the cash balance in the special account was restored and carried forward to the following year. Almost every year thereafter unobligated funds from the regions enabled the cash balance in the special account to be largely restored, thus providing a small but immensely valuable cash reserve to supplement the meagre discretionary funds otherwise available for smallpox eradication through Headquarters accounts.

By 1969, most countries had begun eradication programmes and the problem of lack of funds replaced that of utilizing budgeted allocations. As Henderson wrote to the regional smallpox adviser in the Americas (21 February 1969):

"I am concerned about the problem of money this year for I am afraid we will be very hard pressed indeed. We could use substantially more in the African Region; the Eastern Mediterranean Region has requested some additional [funds] ... and the South-East Asia Region, if the Indian programme accelerates as expected, could use everything we have. I am afraid the honeymoon is over with respect to finances."

It was also pointed out that Brazil, the only endemic country in the Region of the Americas, had already received substantial resources, including funds released in 1967 by the South-East Asia Region, and it was suggested that the Region of the Americas might reciprocate by releasing some of its funds for use elsewhere. However, such transfers of funds were not customary and this proposal was rejected, as were similar subsequent ones.

To achieve a more appropriate distribution of funds, the next best approach seemed to be to attempt to change the regional allocations from year to year to reflect more accurately the relative balance of needs in the different regions. The first allocations, in 1967, had necessarily been arbitrary ones, since it had not been possible at that time to make accurate estimates of need by region. Up to 1970, the allocations remained essentially unchanged but, by then, it was increasingly apparent that far less would be required in the Americas during future years but far more in Asia and Africa and that a reapportionment based on longer-term requirements was needed. Throughout 1970, Smallpox Eradication unit staff worked closely with those in the regions to reach a consensus on future needs. Towards the end of the year, however, the unit was informed that proposals based on these analyses would not be approved by the Director-General. Although the exercise had proved futile, it was hoped that it might still be possible at least to reduce the allocation to the Americas and to increase it in other regions. In a memorandum (dated 30 December 1970) to his Assistant Director-General, Henderson pointed out:

"Plentiful funds are available in the Region of the Americas as confirmed in discussions in Washington during December ... all concerned feel confident that smallpox transmission in the Americas will be interrupted in 1971. It is proposed that smallpox eradication funds be used to strengthen surveillance activities [in the Americas] ... However, even if gilt-edged support is provided to this enterprise, it is agreed that it would be difficult to expend more than $250–300 000 per year [of a budgeted US$569 000]."

The proposed change in allocation was discussed with the Regional Director for the Americas, who agreed with the budget analysis but pointed out that he needed more funds for malaria eradication and asked for some sort of trade-off so as to maintain his regional budget at a more constant level. The Director-General decided, however, not to alter the regional allocations for smallpox eradication for 1971 and, from 1972, the practice of identifying a specific allocation for smallpox eradication was discontinued. This ended the efforts to develop plans for the better deployment of funds from WHO's regular budget. After 1971, it was no longer required that a prescribed minimum amount should be spent on smallpox eradication; the regional directors allocated funds from their overall allotments on the basis of their sense of the programme's priority in relation to the other needs in their regions.

When inflation is taken into account, as was customary each year in preparing WHO's overall budget, the Organization's annual expenditures for the programme up to 1976 were close to the appropriation of US$2.4 million originally approved by the Health Assembly in 1966 (Table 10.5). However, as the number of endemic countries decreased, increasing problems were encountered in obtaining the support necessary to complete the programme and to permit certification, as is shown by a memorandum of 6 January 1975 from Henderson to the Director-General:

"We may face some difficult questions at the Executive Board in regard to the smallpox budget

which we should be prepared for. In November, a special appeal was made by the Director-General for additional funds for the smallpox programme. The importance of the programme and the high priority given to it by the Organization was emphasized. Only $2.1 million of the $3.3 million requested has so far been received but we know of at least five additional countries which have indicated that additional support might be forthcoming.

"The difficult problem about which questions will almost certainly be forthcoming is why the Organization cut the smallpox allocations (by 29%) if it accords the programme such high priority and is asking for special donations. The budget cuts are evident not only in the Regions but also at Headquarters.

"As the first knowledge which I had in regard to the budget levels was when I received Official Records No. 220 [Proposed Programme and Budget for 1976–1977], I find it difficult to contrive a suitable answer which might be proposed. And yet, an inappropriate response could be most damaging, as I'm sure you would agree."

Questions were asked by the Board but the budget was not changed.

Other Types of Assistance to Programmes

As has been mentioned earlier, it was expected that two-thirds of the total costs of the smallpox eradication programme would be met by international agencies other than WHO and by voluntary contributions to governments or to the Special Account for Smallpox Eradication in the WHO Voluntary Fund for Health Promotion. In view of the level of support for smallpox eradication during 1959–1966 (see Chapter 9), this originally seemed to be an unrealistic expectation, but such contributions eventually amounted to US$66.9 million over the period 1967–1979 (Table 10.6).

The different types of contribution are, for the most part, considered together in this section, since it is somewhat arbitrary to identify some as bilateral contributions, some as support to the Special Account for Smallpox Eradication and some as contributions by other international organizations. For example, the substantial cash contributions made by Denmark, Norway and Sweden to programmes in Bangladesh and India during 1974–1977 were provided through the special account for administrative convenience but were a part of the bilateral assistance funds already allocated for use in these countries. Similarly, support from two United Nations organs, the United Nations Emergency Operation (UNEO) in Bangladesh in 1972 and the Office of the United Nations Disaster Relief Co-ordinator (UNDRO) in Somalia in 1977, consisted of supplies and equipment provided by national governments in response to emergency appeals rather than of funds from the established budgets of these organs.

Throughout the programme, an effort was made to account for and place a cash value on the support provided by different agencies. The data as presented, however, suggest a greater precision and completeness in accounting than is, in fact, the case. Many of the contributions were in kind rather than in cash. When a contribution was provided through the Voluntary Fund for Health Promotion, the donor was responsible for

Table 10.5. Expenditure on smallpox eradication from the WHO regular budget in real and constant dollars, 1967–1979 (US$)

Year	Headquarters	Interregional	African Region	Region of the Americas	South-East Asia Region	Eastern Mediterranean Region	Western Pacific Region	Total (US$)	Total in terms of 1967 US$
1967	157 076	111 476	460 090	742 063	295 281	573 999	55 831	2 395 816	2 395 816
1968	180 086	102 511	722 141	815 574	555 634	348 886	3 940	2 728 772	2 647 209
1969	177 966	163 498	951 237	669 142	273 406	649 938	4 491	2 889 678	2 716 933
1970	217 060	83 153	919 020	579 164	460 709	722 587	6 208	2 987 901	2 719 976
1971	219 047	123 574	942 962	503 408	573 279	702 999	4 767	3 070 036	2 652 910
1972	240 460	137 430	1 000 040	481 819	787 081	654 801	2 858	3 304 489	2 702 841
1973	308 490	235 606	694 770	191 259	1 002 489	735 975	0	3 168 589	2 445 327
1974	281 440	273 912	278 599	143 831	1 110 656	960 030	2 838	3 051 306	2 213 845
1975	292 089	408 083	156 130	117 687	1 546 243	540 669	0	3 060 901	2 079 423
1976	480 037	988 866	110 323	0	601 825	1 366 648	0	3 547 699	2 265 525
1977	415 112	1 137 518	26 048	0	439 507	163 130	0	2 181 315	1 304 056
1978	310	504 200	6 944	0	114 646	109 872	0	735 972	409 988
1979	0	344 855	0	0	67 777	30 142	0	442 774	228 604
Total	2 969 173	4 614 682	6 268 304	4 243 947	7 828 533	7 559 676	80 933	33 565 248	26 782 452

Table 10.6. Contributions for smallpox eradication in cash or in kind to the WHO Voluntary Fund for Health Promotion, Special Account for Smallpox Eradication, and from sources of bilateral support, 1967–1979 (US$)

Contributor	Total	Voluntary Fund for Health Promotion, Special Account for Smallpox Eradication		Bilateral support (cash and kind)
		Cash	Kind	
Australia	33 625	33 625	–	0
Austria	75 500	5 000	–	70 500
Argentina	13 275	–	13 275	0
Belgium	378 800	–	378 800	0
Brazil	128 925	–	128 925	0
Cameroon	707	707	–	0
Canada	2 505 061	1 306 779	1 156 282	42 000
Colombia	3 002	–	3 002	0
Czechoslovakia	41 118	–	41 118	0
Denmark	1 083 062	1 083 062	–	0
Finland	110 623	19 663	90 960	0
German Democratic Republic	26 417	–	26 417	0
Germany, Federal Republic of	503 767	127 004	–	376 763
Ghana	3 273	3 273	–	0
Greece	23 000	23 000	–	0
Guinea	18 529	–	18 529	0
Hungary	33 500	–	33 500	0
India	503 691	–	207 291	296 400
Iran	874 000	500 000	374 000	0
Japan	634 198	268 400	223 598	142 200
Jordan	140	–	140	0
Kenya	168 000	–	168 000	0
Kuwait	12 992	12 992	–	0
Luxembourg	6 541	6 541	–	0
Monaco	2 419	–	2 419	0
Netherlands	2 803 133	2 613 393	177 870	11 870
New Zealand	10 500	–	10 500	0
Nigeria	16 036	16 036	–	0
Norway	998 530	998 530	–	0
Peru	3 000	–	3 000	0
Philippines	5 000	–	5 000	0
Poland	3 500	–	3 500	0
Saudi Arabia	200 000	200 000	–	0
Sweden	15 689 584	15 408 504	281 080	0
Switzerland	372 169	118 659	219 910	33 600
Thailand	3 565	–	3 565	0
Uganda	12 077	12 077	–	0
Union of Soviet Socialist Republics	8 805 610	–	3 531 913	5 273 697
United Kingdom	1 020 924	1 010 924	–	10 000
United States of America	24 974 003	6 339 900	1 258 408	17 375 695
Yugoslavia	26 000	–	26 000	0
Zaire	2 500	2 500	–	0
Council of Arab Ministers' Fund for Health Development	20 350	–	20 350	0
Japan Shipbuilding Industry Foundation	1 769 344	1 769 344	–	0
OXFAM	103 104	3 104	–	100 000
Tata Iron & Steel Co. Ltd (India)	536 399	–	–	536 399
Other	52 238	26 806	25 432	0
Subtotal	64 611 731	31 909 823	8 432 784	24 269 124
UNDP (United Nations Development Programme)	299 344	–	–	299 344
UNDRO (Office of the United Nations Disaster Relief Coordinator)	470 849	–	–	470 849
UNEO (United Nations Emergency Operation)	750 000	–	–	750 000
UNICEF (United Nations Children's Fund)	427 878	–	–	427 878
UNROD (United Nations Relief Operation, Dacca)	415 500	–	–	415 500
Subtotal	2 363 571	–	–	2 363 571
Total	66 975 302	31 909 823	8 432 784	26 632 695

assigning a cash value to it but different donors assigned different values to the same product. For example, most vaccine was valued at US$10–16 per 1000 doses but values as high as US$256 per 1000 doses were assigned by some donors. The average value for all vaccine contributed worked out at US$17 per 1000 doses, although estimates of the actual costs of vaccine production in the industrialized countries in the early 1970s were in the range of US$30–40 per 1000 doses.

It may be noted that in several instances the amounts in Table 10.6 are different from those recorded by the Global Commission for the Certification of Smallpox Eradication in Annex 16 to its Final Report (World Health Organization, 1980). The differences are the consequences of adjustments made in the light of more recent information. In addition, Annex 16 included the value of some bilateral contributions made before 1967 (notably by the USA and the USSR) and of cash and vaccine pledged during the period 1967–1979 by India, the USSR and the Japan Shipbuilding Industry Foundation but received after 1979; these amounts have been omitted from Table 10.6.

An attempt was also made to place a cash value on the services of volunteer personnel. For accounting purposes, a figure of US$750 per month was assigned, an estimate provided by one of the principal donor governments. This figure, as well as a number of other approximations that were made, undoubtedly understates to some degree the value of gifts in kind. All but impossible to estimate, and not included here, is the value of services provided by many local, non-governmental groups, such as the League of Red Cross and Red Crescent Societies; Kiwanis, Lions and Rotary Clubs; youth groups, such as the Boy Scouts and Girl Guides; and missionary groups. In a number of countries such groups were most helpful in organizing vaccination campaigns, mobilizing public support and, sometimes, performing vaccinations. A few contributed funds in support of local programmes, although in comparison with national and international contributions, the cash value of all such contributions was not large.

Although voluntary contributions were recognized by the Health Assembly to be an essential adjunct to the WHO regular budget, such support was difficult to obtain. Every year, Health Assembly resolutions requested all countries to provide additional support and every year the Director-General sent letters to all Member States and to relevant international agencies, referring to the Health Assembly resolution and asking for help. Smallpox eradication programme staff regularly met potential donors at the World Health Assembly and during special visits to national capitals and embassies; special meetings of potential donors were convened; and influential national figures who were sympathetic to the programme were regularly contacted to seek their good offices in obtaining support. Despite these efforts and despite the fact that the eradication of smallpox would be of great benefit to all countries, contributions were modest at best. This may have reflected a certain scepticism as to the feasibility of eradication; however, it also reflected the fact that WHO, except for malaria eradication, had not previously been active in seeking supplementary contributions and governments were unaccustomed to making them. As Table 10.7 shows, except in respect of malaria eradication, the contributions to the special accounts that made up the Voluntary Fund for Health Promotion did not exceed US$2 million in any year until 1968, and of all the contributions made between 1967 and 1975, 18% were for smallpox eradication.

Vaccine for the programme was obtained entirely from voluntary contributions or local production. From 1967 to 1979, 27 countries contributed 407 million doses of vaccine to the Voluntary Fund, more than 60% of this coming from the USSR. Although industrialized countries provided most of the donated vaccine, notable contributions of vaccine were also made by Argentina, Brazil, Colombia, Guinea, India, Iran, Kenya, Peru, Philippines and Thailand.

Efforts to obtain support from UNICEF and the United Nations Development Programme (UNDP) proved disappointing, although both agencies had previously given significant support to other WHO programmes, as well as some support for smallpox eradication before 1967. Between 1967 and 1972, UNICEF provided US$427 878 for vaccine and vaccine production equipment but none thereafter—a policy reflecting its disappointment with the lack of progress in malaria eradication and its decision not to support another attempt to eradicate a disease. The possibility of support from UNDP was explored with the resident

Table 10.7. Contributions in cash or in kind to the WHO Voluntary Fund for Health Promotion or to special accounts,[a] by year, 1956–1979 (US$)[b]

Year	Malaria eradication	Smallpox eradication	Other	Total
1956	68 096	–	–	68 096
1957	5 046 909	–	–	5 046 909
1958	169 506	285 000	300 000	754 506
1959	6 284 766	–	500 000	6 784 766
1960	1 202 317	104 010	622 488	1 928 815
1961	4 464 094	96 000	1 266 674	5 826 768
1962	590 437	3 800	573 115	1 167 352
1963	2 718 815	5 060	1 572 479	4 296 354
1964	163 300	316 694	1 148 857	1 628 851
1965	86 890	24 936	843 843	955 669
1966	77 225	40 780	1 449 518	1 567 523
1967	37 050	202 305	611 747	851 102
1968	46 711	313 233	2 233 294	2 593 238
1969	36 854	239 457	1 408 438	1 684 749
1970	52 977	337 820	2 352 518	2 743 315
1971	85 339	810 708	5 957 930	6 853 977
1972	157 009	780 632	4 368 568	5 306 209
1973	252 392	1 288 137	10 683 838	12 224 367
1974	257 823	4 533 310	11 032 822	15 823 955
1975	1 307 009	10 522 835	20 535 705	32 365 549
1976	388 367	9 448 523	22 393 979	32 230 869
1977	973 150	5 272 392	28 886 320	35 131 862
1978	7 134 651	5 690 337	35 129 741	47 954 729
1979	2 117 617	902 918	29 101 543	32 122 078
Total	33 719 304	41 218 887	182 973 417	257 911 608

[a] Special accounts were amalgamated, as sub-accounts, into the Voluntary Fund for Health Promotion when that was established by the World Health Assembly in 1960 (except for the Malaria Eradication Special Account, which was placed in the Voluntary Fund in 1964).

[b] Excludes income from interest, revenue from sales, and savings.

representatives in several countries, but lack of interest, the complexities involved in developing suitable proposals and the delays in securing their approval restricted support to US$299 344.

Between 1967 and 1970, over half of all international expenditure on smallpox eradication was met by bilateral contributions (Table 10.8), representing primarily United States support for the programme in western and central Africa and contributions of vaccine by the USSR to India and several smaller Asian countries. With the achievement of smallpox eradication in western and central Africa in 1970, support for that programme began to be phased out and India, during the early 1970s, began to rely increasingly on domestically produced vaccine. Bilateral contributions diminished proportionately, and after 1972 exceeded US$1 000 000 only in 1974 and 1975.

Expenditure from the Special Account for Smallpox Eradication up to the end of 1973 was accounted for primarily by the distribution of donated vaccine. The amounts increased steadily over the years, reaching US$845 150 in 1973. Two-thirds of the expenditure on smallpox eradication in 1973, however, were met by WHO's regular budget.

Contributions to the Voluntary Fund increased significantly from 1974 onwards. In the autumn of 1973, smallpox eradication activities had been intensified in Asia, but the problems encountered in India proved far more formidable than had been anticipated (see Chapter 15) and, in response to special appeals for assistance, Sweden began to contribute substantial sums to the Voluntary Fund for use in that country, amounting in total to more than US$9 million during 1974–1976. As difficulties mounted in Bangladesh as well, Sweden, and later Norway and Denmark, joined together to provide more than US$5 million for its programme. Substantial additional assistance for India was also provided by the Tata Iron and Steel Company of India, by Iran and by OXFAM.

In 1974, it was also possible to intensify the programme in Ethiopia, the only endemic country outside Asia, thanks to support from the United States Public Health Service, which began to make funds available for leasing helicopters, nearly US$2 million being provided for this purpose from 1974 to 1977. AID contributed US$3 million to the Voluntary Fund in 1976–1977 in support of the Ethiopian programme and additional assistance was provided by Australia, Austria, Finland, the Federal Republic of Germany and Japan. Finally, with the reintroduction of smallpox into Somalia in 1976 (see Chapter 22), special appeals for funds brought contributions from the USA and from UNDRO. Meanwhile, cash contributions which could be used wherever required were provided by Canada, the Netherlands, the United Kingdom, Switzerland and the Japan Shipbuilding Industry Foundation.

By 1977, the year in which the last endemic case occurred, the Voluntary Fund covered more than 70% of all expenditures; during the period of certification activities, 1978–1979, WHO regular budget allocations were sharply decreased and the coverage by the Voluntary Fund increased to 80–90%.

Although the increase in voluntary contributions from 1974 onwards coincided with a growing recognition of the feasibility of global smallpox eradication, the donations proved to be almost as difficult to obtain as in

earlier years. A review of the origin and history of each of the contributions shows that personal, often repeated, appeals by individual members of the smallpox eradication programme staff had to be made in order to obtain each contribution.

SUPPLY OF VACCINE AND VACCINATION INSTRUMENTS

The availability at all times of satisfactory freeze-dried vaccine and vaccination instruments was essential to the successful execution of the programme. Without vaccine and bifurcated needles or jet injectors, programme staff could do nothing; with them, methods could usually be devised to deal, at least to some extent, with shortages of transport and equipment, and so sustain both momentum and morale. Because of the importance of vaccine and vaccination instruments, Chapter 11 is devoted exclusively to the subject. Here, we summarize the methods used to ensure that both were readily available to all endemic countries and to those adjacent to them.

Vaccine Requirements

It had originally, but erroneously, been assumed that the provision of adequate quantities of suitable freeze-dried vaccine would not present a major problem. It was believed that, for most endemic countries, if sufficient vaccine were not already available, it would either be provided in the form of bilateral contributions or soon be produced in the endemic countries themselves. Additional requirements would be met through contributions made through the Voluntary Fund for Health Promotion, the pledged annual contribution of 25 million doses by the USSR being considered almost sufficient for this purpose.

From what was known in 1967, adequate supplies of vaccine appeared to be available. In the Americas a number of laboratories were already producing freeze-dried vaccine and an agreement was signed by the Pan American Health Organization with Connaught Laboratories of Canada to provide for continuing consultation, the training of technicians and the monitoring of vaccine throughout that region. It seemed, therefore, that this region was already self-sufficient, or soon would be. In the African Region, the programme in western and central Africa was being carried out with the assistance of the USA, which provided the necessary vaccine to 20 countries. In virtually all other countries, some type of vaccination programme was in progress and it was assumed that many had already obtained satisfactory vaccine from some source, although it was recognized that additional vaccine would be required if the programmes were to be intensified. In the South-East Asia Region, only Nepal and possibly Indonesia among the endemic countries appeared to require vaccine. India's needs were being met by domestic production and bilateral contributions from the USSR.

Table 10.8. International expenditure on smallpox eradication, 1967–1979 (US$)

Year	WHO regular budget	Voluntary Fund for Health Promotion, Special Account for Smallpox Eradication	Other organs of United Nations system	Bilateral support	Total
1967	2 395 816	194 889	526 476	3 911 700	7 028 881
1968	2 728 772	255 927	116 774	4 163 680	7 265 153
1969	2 889 678	233 635	83 713	4 334 060	7 541 086
1970	2 987 901	375 434	61 644	3 918 307	7 343 286
1971	3 070 036	608 403	34 772	2 377 650	6 090 861
1972	3 304 489	727 581	448 100	1 397 627	5 877 797
1973	3 168 589	845 150	–	997 655	5 011 394
1974	3 051 306	3 127 169	–	1 086 907	7 265 382
1975	3 060 901	8 065 031	631 696	1 494 282	13 251 910
1976	3 547 699	6 629 430	118 304	189 313	10 484 746
1977	2 181 315	6 724 347	470 849	9 780	9 386 291
1978	735 972	4 364 812	–	388 163	5 488 947
1979	442 774	5 491 229	–	–	5 934 003
Total	33 565 248	37 643 037	2 492 328	24 269 124	97 969 737

Afghanistan and Burma were also receiving vaccine from the USSR. In the Eastern Mediterranean Region, Pakistan was thought to be producing sufficient vaccine for its own needs in a laboratory in Dhaka, and the quantities required for Ethiopia, Somalia, the Sudan and Yemen were thought not to be great.

In 1967, a detailed survey of the amount and quality of vaccine being produced throughout the world revealed that the situation was much less satisfactory than had been thought. It was discovered that much of the vaccine then in use was produced by laboratories which did not test it for stability, while some laboratories determined potency simply by vaccinating a group of young children. When tested by the 2 WHO reference laboratories, much of the vaccine from developing countries and some from industrialized ones did not meet the international standards.

During the first 2–3 years of the Intensified Programme, the provision of vaccine was not a major problem, however, because of the time required for national programmes to organize activities aimed at increasing substantially the number of vaccinations performed. Of the countries in which major programmes began in 1967, Brazil produced sufficient vaccine for its own needs and, as has already been mentioned, the countries of western and central Africa were supplied by the USA. To ensure an adequate supply of vaccine of proven potency to meet the needs of other countries, a number of measures had to be taken quickly: (1) vaccine production laboratories in endemic countries were supported by the provision of consultants, equipment and production manuals; (2) the WHO reference laboratories agreed to test all batches of vaccine produced by newly established laboratories and to participate in research and other activities which would enhance and/or simplify production methods; (3) a system of international quality control was established for all vaccine used in the Intensified Programme, whether locally produced or donated through bilateral assistance or by WHO; (4) vaccination devices were tested and introduced which used less vaccine than conventional techniques; and (5) additional contributions of vaccine were sought. As a result, sufficient vaccine of adequate quality was eventually ensured for every endemic country, although for many years reserve supplies remained perilously low.

Plate 10.24. Ryoichi Sasakawa, President of the Japan Shipbuilding Industry Foundation, presents a cheque for US$500 000 to F. J. Dy, Director of the WHO Regional Office for the Western Pacific in November 1975. Masami Tanaka, Minister of Public Health of Japan, stands between them. The Foundation later increased its support to WHO for smallpox eradication to a total of nearly US$1.8 million, the largest amount given by a nongovernmental organization.

Support for Production Laboratories in Endemic Countries

Of the commonly used vaccines, smallpox vaccine was the easiest to produce and laboratories already existed in a number of developing countries. Priority was given to the support of laboratories in the countries with the largest populations in order both to improve the quality of their vaccine and to increase their capacity, in the expectation that voluntary contributions would meet the needs of others. A first step was to simplify and standardize production methods. The principles on which vaccine production was based were similar throughout the world, but techniques differed widely from one laboratory to another. In 1968, therefore, a meeting of the most experienced vaccine producers was convened to develop a manual (SE/68.3 Rev.2) which described in detail the optimum production procedures. Selected consultants then repeatedly visited laboratories in the endemic countries to help them to improve methods and expand capacity. On the basis of their recommendations, additional equipment and supplies were provided. Vials of seed virus for use in production, as well as

reference specimens for testing, were prepared and distributed by the National Institute of Public Health, Bilthoven, Netherlands; when the laboratories began production, batches of vaccine were tested by one or the other of the two WHO reference laboratories.

Year by year, the quantity of vaccine produced in the developing countries increased and its quality improved. In the South-East Asia Region, Burma became self-sufficient in 1969 and Indonesia in 1970; India's 4 laboratories slowly but steadily increased the quantity and quality of their vaccine. The laboratory in Dhaka likewise increased production to provide sufficient vaccine for East Pakistan, although some additional supply had to be provided during the intensified programme in 1973–1975, in what was then Bangladesh. In the African Region, support was provided to laboratories in Guinea, Kenya and Nigeria in the hope that they might serve as producers for large regions of eastern and western Africa. Kenya, by late 1968, was able to produce sufficient vaccine for several countries in eastern Africa; the laboratory in Guinea took much longer to begin production and never succeeded in producing large quantities; the laboratory in Nigeria produced only a few satisfactory experimental batches. In the Americas, most of the countries conducting programmes quickly became self-sufficient and contributed vaccine to others requiring it. Brazil, as noted above, produced sufficient vaccine for its own needs and, although many batches did not meet international standards, especially for stability, the vaccine was effective provided that it was kept cold until the time of application. The Eastern Mediterranean Region was ultimately to require the largest amounts of vaccine. Efforts to establish a laboratory in Pakistan, the country with the largest population in the region, failed because of national administrative problems, but by 1973 sufficient vaccine to meet most of Pakistan's needs was being provided by Iran. Assistance was also given to laboratories in Ethiopia, Iraq and the Syrian Arab Republic, but none of these succeeded in producing more than small quantities of satisfactory freeze-dried vaccine.

By 1971, approximately 250 million doses of vaccine were being produced annually in the endemic regions, and by then all the vaccine used in national programmes, except in Brazil, met international standards.

Vaccine Donations

Most of the contributed vaccine was provided under bilateral agreements by the USSR, which donated more than 1400 million doses from 1958 to 1979. The USA provided more than 190 million doses, primarily to the western and central African countries, also under bilateral agreements. Contributions from other countries usually amounted to no more than a few million doses each year (see Chapter 11, Table 11.15 for the quantities contributed to WHO between 1967 and 1984). In part, this was because most industrialized countries produced their own vaccines in small national or quasi-national laboratories. Most produced little or no freeze-dried vaccine, preferring instead the glycerolated liquid vaccine, which could be dispensed more conveniently in single-dose capillaries. Although the vaccine had to be kept constantly under refrigeration, this caused little difficulty for the industrialized countries.

Except for the vaccine provided under bilateral agreements by the USSR and the USA, virtually all vaccine contributions were made through the WHO Voluntary Fund for Health Promotion. Until 1967, arranging for the acceptance and shipment of vaccine contributed to WHO was complicated and time-consuming, usually requiring 6–18 months (see Chapters 9 and 11). Several measures were therefore taken to reduce the processing interval to only 6–8 weeks. The Smallpox Eradication unit assumed responsibility for arranging for tests of batches of vaccine proposed for donation and the National Institute of Public Health, Bilthoven, agreed to examine specimens as soon as received. Specimens were shipped promptly and the results reported by telex or telephone. One obstacle to rapid processing was the requirement that vaccine titres should be determined after incubation for 4 weeks at 37 °C. When it was shown in 1969 that all vaccine batches with an adequate titre after incubation for 1 hour at 100 °C also met conventional stability tests (Arita, 1973), it was possible further to reduce the time required for testing by 4 weeks. Another problem had been that of arranging for the prompt shipment of vaccine from donor laboratory to recipient country. Many donors waited until vaccine was requested before beginning production but, even when it was available in stock, many delays occurred in arranging for international shipment. WHO

Table 10.9. Quantities of vaccine supplied annually from vaccine donated to WHO (thousands of conventional doses)[a]

Country or organization	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Total
Africa														
Benin	0	0	0	0	0	0	0	2	0	0	0	672	0	674
Botswana	0	0	0	0	245	445	100	190	194	256	292	220	237	2 179
Burundi	1 000	200	0	725	758	315	0	250	0	177	0	64	0	3 489
Cameroon	0	0	0	0	0	0	300	0	0	0	830	0	0	1 130
Cape Verde	0	0	0	0	0	0	0	0	155	80	64	6	32	337
Central African Republic	0	0	0	0	0	0	120	0	0	0	0	224	0	344
Chad	0	0	0	0	0	0	300	0	0	0	0	360	0	660
Comoros	0	0	0	0	0	0	0	0	0	120	100	0	0	220
Congo	0	0	0	0	0	0	190	10	0	0	0	496	0	696
Djibouti	0	0	0	0	0	0	0	0	0	0	0	100	0	100
Equatorial Guinea	0	0	17	0	0	0	0	0	0	0	64	0	0	81
Ethiopia	0	0	0	315	4 323	2 432	1 998	2 468	2 384	5 720	3 048	560	25	23 273
Gabon	0	0	0	0	0	100	65	0	0	0	0	0	0	165
Gambia	0	0	0	0	0	0	0	0	0	0	46	32	0	78
Ghana	0	0	0	0	0	0	0	22	0	10	18	0	0	50
Guinea	749	0	0	0	0	0	0	0	0	0	0	0	0	749
Guinea-Bissau	0	0	0	0	0	0	0	0	100	0	0	0	0	100
Lesotho	0	0	0	210	70	105	20	0	40	90	152	48	96	831
Liberia	250	0	0	0	0	0	20	0	0	0	0	128	0	398
Malawi	0	508	300	1 007	525	1 000	500	1 007	953	500	610	600	315	7 825
Mali	100	0	0	0	0	0	810	295	0	0	0	320	0	1 525
Mauritania	0	0	0	0	0	90	260	107	80	0	64	224	0	825
Mauritius	0	100	158	35	105	70	105	35	32	32	35	32	37	776
Mozambique	0	0	0	0	0	0	0	0	0	848	1 824	1 968	375	5 015
Niger	0	0	0	0	0	0	0	0	0	675	0	0	0	675
Nigeria	0	0	0	0	0	0	2 010	0	0	0	0	0	0	2 010
Rwanda	0	0	1 050	500	0	112	205	280	204	211	198	536	0	3 296
Sao Tome and Principe	0	0	0	0	0	0	0	0	0	20	0	6	20	46
Sierra Leone	550	250	0	0	0	0	0	0	0	0	0	60	0	860
Somalia	66	30	35	370	105	623	624	650	608	1 151	3 904	1 524	0	9 690
Sudan	2 010	3 658	2 490	3 500	244	1 990	1 485	490	512	256	640	416	542	18 233
Swaziland	0	0	0	0	0	0	80	47	0	100	69	64	64	424
Togo	0	0	0	0	0	0	125	0	0	0	0	0	0	125
Tunisia	0	0	0	210	1 085	560	1 110	600	256	0	0	0	0	3 821
Uganda	0	800	1 100	2 850	1 000	495	500	510	501	263	240	256	0	8 515
United Republic of Tanzania	1 014	0	2 500	2 000	1 990	968	820	1 984	1 017	550	2 074	512	0	15 429
Upper Volta (Burkina Faso)	0	0	0	0	0	0	0	0	0	0	1 607	312	10	1 929
Zaire	2 000	3 500	3 285	6 259	10 945	2 000	2 985	2 000	1 000	2 024	1 726	2 024	1 055	40 803
Zambia	610	1 800	1 208	1 398	2 061	1 820	1 700	1 842	1 078	2 000	1 284	1 408	180	18 389
Americas														
Brazil	0	0	0	1 255	0	0	0	0	0	0	0	0	0	1 255
Honduras	200	0	0	0	0	0	0	0	0	0	0	0	0	200

Asia														
Abu Dhabi[b]	0	0	0	0	35	15	0	0	0	0	0	0	0	50
Afghanistan	698	0	0	0	0	515	0	0	0	192	224	0	0	1 629
Bahrain	0	0	0	0	70	55	0	0	0	0	0	0	0	125
Bangladesh	0	0	300	0	0	948	4 783	11 331	19 026	0	0	0	0	36 388
Burma	1 500	1 500	76	0	0	0	0	0	0	0	0	0	0	3 076
Democratic Kampuchea	0	1 200	0	0	0	0	0	0	0	0	0	0	0	1 200
Democratic Yemen	0	150	35	0	350	0	220	602	0	300	0	96	62	1 815
Dubai[b]	100	0	0	0	35	105	0	0	0	0	0	0	0	240
India	1 000	0	0	0	0	0	0	1 606	0	0	0	0	0	2 606
Indonesia	1 000	2 350	450	300	0	0	0	0	0	0	0	0	0	4 100
Iran	0	0	0	0	2 026	11 096	0	0	0	0	0	0	0	13 122
Iraq	0	0	0	0	0	5 080	0	0	0	0	0	0	494	5 574
Kuwait	140	0	0	0	0	0	0	0	0	0	0	0	0	140
Lao People's Democratic Republic	100	900	0	500	1 025	0	0	10	0	0	0	0	0	2 535
Lebanon	1 000	1 000	0	283	2 006	1 388	250	502	0	10	65	60	0	6 564
Maldives	0	0	0	70	0	0	0	0	0	0	0	0	0	70
Mongolia	0	0	0	0	210	0	125	125	96	128	0	256	120	1 060
Nepal	450	2 900	2 915	700	1 995	5 875	3 340	2 800	0	1 024	2 048	1 024	0	25 071
Oman	0	0	0	0	454	0	65	0	0	0	0	0	95	614
Pakistan	0	420	4 298	9 005	11 930	3 495	9 085	14 245	7 524	5 000	2 016	1 500	1 000	69 518
Saudi Arabia	0	0	0	287	414	0	0	0	0	0	0	0	0	701
Sri Lanka	0	0	0	0	0	955	65	467	0	0	0	0	0	1 487
Syrian Arab Republic	0	0	0	0	0	1 010	0	0	0	0	0	0	0	1 010
UNRWA	0	0	87	210	0	173	0	171	73	82	163	100	109	1 168
Viet Nam	0	0	67	0	0	0	0	0	0	0	0	0	0	67
Yemen	250	0	315	245	735	210	245	145	450	0	252	100	64	3 011
Europe														
Cyprus	5	0	0	0	0	0	0	9	27	0	0	0	0	41
Yugoslavia	0	0	0	0	0	500	0	0	0	0	0	0	0	500
WHO HQ Miscellaneous	15	50	0	0	0	48	66	0	0	0	0	0	8	187
Oceania														
New Hebrides (Vanuatu)	0	0	0	0	0	0	0	0	0	3	0	0	0	3
Total	14 807	21 316	20 686	32 234	44 741	44 593	34 676	44 802	36 310	21 822	23 657	16 308	4 940	360 892

[a] From 1968 onwards, bifurcated needles started to be used for vaccination, enabling 1 dose to be used for the vaccination of 4 people. Hence numbers of doses are not necessarily the same as numbers of vaccinations performed. In addition, wastage of vaccine in the field must be taken into account. It can safely be assumed that the number of doses should be multiplied by 2 to give the number of vaccinations. Supply of vaccine by WHO was discontinued after 1980 when the eradication of smallpox was confirmed by the World Health Assembly.

[b] Now part of the United Arab Emirates.

therefore decided to request that all vaccine, after testing, should be shipped to Geneva for storage in refrigerated facilities leased by WHO. With this vaccine reserve, WHO administrative staff were able to send out vaccine within 48–72 hours of receiving a request.

During 1967–1979, more than 360 million doses of vaccine were distributed to some 70 countries or organizations (Table 10.9), both vaccine and bifurcated needles being made available to all developing countries that requested them whether or not they were conducting a special eradication programme. Between 1967 and 1969, 15–20 million doses were distributed annually, a figure which increased to 30–45 million doses during the period 1970–1975. Until 1973, however, the balance between demand and available contributions remained a precarious one (Fig. 10.3). Nevertheless, no programme was suspended for lack of vaccine although, in some countries and during some periods, vaccine reserves provided enough for only 1–2 weeks of continuing operations.

Success in ensuring an adequate supply of vaccine must be attributed, in part, to the use of the bifurcated needle from 1968 onwards. Most of the vaccine was supplied in containers which provided 0.20–0.25 ml, sufficient to vaccinate 20–25 persons by conventional scarification methods and 4–5 times that number with the bifurcated needle. For purposes of record-keeping, however, each vial continued to be regarded as containing 20–25 doses. For technical reasons vaccine could not be packaged in vials containing smaller quantities than 0.20–0.25 ml; had it been possible to do so, wastage would have been reduced, since the prescribed practice was to discard any reconstituted vaccine that remained at the end of the day.

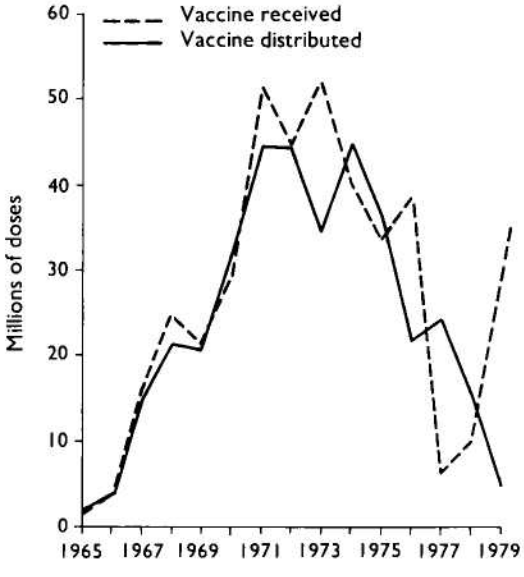

Fig. 10.3. Donations of smallpox vaccine to WHO: numbers of doses received and distributed, by year, 1965–1979.

The vaccine supply depot in Geneva proved invaluable and most vaccine was dispatched from it. In the interests of economy, however, some donated vaccine was sent direct from the producer to recipient countries. When Kenya began to produce more vaccine than it required, stocks were shipped direct from its laboratory to neighbouring countries; Iran's contributions were shipped to Pakistan; South American countries sent vaccine to one another; and Indian bilateral contributions were shipped direct to Bangladesh, Nepal and Sri Lanka in 1975–1976. Several regional offices proposed that regional depots should be established, but the small reserves available made this impracticable. When, in 1976, vaccine reserves at last began to accumulate, a second depot was created in New Delhi at the Regional Office for South-East Asia. Unfortunately, mechanical problems with the refrigeration units and frequent interruptions in the electricity supply made it necessary to close this depot down, and the international reserve of vaccine was subsequently stored by WHO in two locations in Switzerland—Geneva and Lausanne.

Development of Vaccination Devices

New vaccination devices used less vaccine than, and eventually replaced, the traditional scarification instruments used before 1967. Smallpox vaccination with jet injectors, first tested in a pilot project in 1965, was rapid and required only one-third as much vaccine as conventional methods. Jet injectors were widely used in three of the initial major campaigns—in Brazil (see Chapter 12), in western and central Africa (see Chapter 17) and in Zaire (see Chapter 18). However, they were little used elsewhere, partly because of the difficulty of maintaining and repairing them but mainly because the simple, effective and cheap bifurcated needle became available

in 1968, only a year after the Intensified Programme began.

The historical development of the bifurcated needle is described in Chapter 11, in which the needle itself and the containers used for sterilizing needles before use are illustrated (see Plate 11.15). Introduced in 1968 for use with a multiple-puncture technique devised by Henderson and Arita, bifurcated needles had replaced traditional methods in most countries by the end of 1968 and were in use everywhere by 1970. They cost only US$5 per 1000 and could be reused repeatedly after sterilization. Besides conserving vaccine, they were so simple to use that a local villager could be trained in only 10–15 minutes to reconstitute vaccine and to perform effective vaccinations.

Vaccine Practices and Complications

The WHO Handbook recommended that, in endemic and neighbouring countries, everyone, including infants, should be vaccinated. The only recognized contraindication to vaccination related to "individuals who were obviously severely acutely ill" and whose death, if it occurred, might be mistakenly attributed to vaccination. This recommendation was based on the rationale that in endemic areas the risks of complications following vaccination were far lower than those associated with contracting variola major or even variola minor. Moreover, it was recognized that most vaccinations would be performed by vaccinators who would be unable to identify conditions commonly accepted as contraindications to vaccination in non-endemic countries, such as immunological disorders, neoplastic disorders affecting the reticuloendothelial system, and treatment with corticosteroids, antimetabolic drugs or other chemotherapy.

The WHO Handbook described several possible vaccination techniques: multiple-pressure or scratch using a needle or rotary lancet, and the jet injector. An important change from conventional vaccination practice at the time was the recommendation that "the best skin preparation is none at all", and that "if the site is obviously caked with dirt, a cloth moistened with water may be used to wipe the site". This recommendation was based on a number of studies which had demonstrated that conventional methods for cleansing the skin with acetone or alcohol had little effect in reducing the number of bacteria but could destroy or partially destroy vaccinia virus if the vaccine was applied before the liquid had dried.

During the programme, few serious complications were observed which could be attributed to vaccination. The usual response to vaccination—a pustule, with sometimes a sore arm and fever—was readily tolerated although it caused some people to refuse vaccination—for example, agricultural workers during the harvest period. Disseminated vaccinia was observed in only a few patients. Cases of post-vaccinial encephalitis, a far more serious complication, undoubtedly occurred but because of the large number of prevalent illnesses which caused cerebral symptoms (e.g., malaria), it was difficult to know whether cases of encephalitis-like illness were complications of vaccination or were due to other causes. An unusual group of complications occurred in Ethiopia among nomads of the northern Ogaden desert, a number of whom, following primary vaccination, developed a deep, non-pustular crateriform lesion at the vaccination site which penetrated as deep as the muscle fascia. All those affected reported that they had applied the ashes of a thorny shrub to the lesion. Efforts to interest pharmacologists in this phenomenon were unsuccessful but the problem ceased when a sulfa powder was distributed and the nomads were advised to use this instead of the ashes.

SURVEILLANCE AND NOTIFICATION OF SMALLPOX CASES

Whereas, up to 1967, smallpox eradication programmes consisted entirely of mass vaccination campaigns, from 1967 onwards they also included surveillance. Little attention had been given to surveillance and the notification of smallpox cases either internationally or within countries up to that time; in the endemic countries, there were no nationally organized programmes designed to investigate and contain reported outbreaks. From 1967, however, the indicator used for measuring the progress of the programme ceased to be the total number of vaccinations and was replaced by the numbers of reported cases of smallpox and of endemic countries. Epidemiological analysis of the cases provided important information from the point

of view of the strategy and tactics to be employed and the allocation of resources.

The difficulty of explaining the concept of surveillance to programme staff and of gaining their acceptance of it was not appreciated, however, when the programme began. Mass vaccination campaigns were familiar and well understood but because they were complex to organize and execute, little time and few resources were usually available for surveillance. Incorporating into programmes what had seemed to be a simple, basic concept required much of the time and energy of the senior WHO smallpox eradication programme staff.

The Concept of Surveillance

The concept of a nationally supervised programme for reporting and investigating smallpox cases and containing outbreaks had, as its antecedent, the disease surveillance programmes of CDC in the USA (Langmuir, 1963). Dr Alexander Langmuir, its chief epidemiologist, had fostered the concept of surveillance since his appointment in 1949. He attributed the genesis of the concept to William Farr, who had been the superintendent of the Statistical Department of the Registrar General's Office of England and Wales in the 19th century. Farr's epidemiological analysis of cases and deaths over many years and by age group, area and season, made it possible to formulate hypotheses as to the way in which diseases were spread, which in turn suggested possible control measures and enabled forecasts of future trends in disease incidence to be made.

Dr Langmuir defined surveillance as the "continued watchfulness over the distribution and trends of incidence through systematic collection, consolidation and evaluation of morbidity and mortality reports and other relevant data". He pointed out that "intrinsic in the concept is the regular dissemination of the basic data and interpretations to all who have contributed and to all others who need to know". In developing surveillance in the USA, he focused primarily on diseases for which control measures were available, beginning with malaria, sylvatic plague and leprosy, and subsequently extended it to include diphtheria, poliomyelitis and other diseases. Working with state and local health officials, he and his staff obtained detailed information about reported cases, including confirmation of the diagnosis by laboratory study and basic data regarding age, sex, race and place of residence and, depending on the disease, information regarding vaccination status, possible place of exposure, etc. These data were regularly analysed, appropriate control measures recommended and surveillance reports prepared and widely distributed.

Henderson had worked with Dr Langmuir since 1955 and had served from 1961 to 1965 as chief of the Surveillance Section at CDC. It seemed to him only logical to endeavour to apply the principles of surveillance to the eradication of smallpox. This was stated in the Director-General's report to the Nineteenth World Health Assembly (World Health Organization, 1966b; see Chapter 9), which Henderson, as a consultant to WHO, had helped to prepare. This approach was strongly supported by Dr Raška, Director of the Division of Communicable Diseases, who had been a keen proponent of epidemiological surveillance while working in his own country, Czechoslovakia (Raška, 1964).

The concept of surveillance as applied to the smallpox programme was succinctly described in the WHO Handbook as follows:

> "The primary objective of the smallpox programme is the eradication of this disease. Surveillance is thus an essential component of the programme since the term 'eradication' implies that the number of indigenous cases of smallpox reach '0' ... Surveillance represents a great deal more than case reporting alone. It is composed of several components:
>
> (a) The routine, systematic collection of data, amplified appropriately by special field investigations and studies
> (b) The concurrent analysis and interpretation of reported data and studies
> (c) The initiation of appropriate definitive action including field investigation, epidemic control, modification of operational campaign procedures, recommendations regarding vaccination, etc.
> (d) Widespread dissemination of the compiled and interpreted data to principal reporting sources and to others concerned with disease control activities."

The Routine Systematic Collection of Data

A reporting network which provided for the collection of epidemiological data regarding each case of smallpox was the foundation of the system. Its goal was to ensure that each week all known cases of smallpox would be

reported by the peripheral health units in each country, through intermediate administrative units, such as districts and provinces, to national and, ultimately, to international authorities. The concept was simple, but there were formidable problems at every level in perfecting such a system.

Although this section deals primarily with surveillance at the international level, certain features and problems of national data collection systems need to be described in order to appreciate the quality of the data being provided in 1967 to WHO by national authorities in the endemic countries.

Reported cases of smallpox, which would be routinely notified if the system were functioning properly, inevitably represented only a portion of all the cases which actually occurred. The basic network of reporting units—health clinics, hospitals and dispensaries—documented only those who presented themselves for treatment. Many patients had no access to health care or did not go to health care units for fear of unwanted forcible isolation in a hospital or because they knew that there was no effective treatment. They could be discovered through searches or by field investigations of known outbreaks, but few health services undertook such activities. Even where there was complete notification of all cases seen by health units, the data provided only an indication of trends in incidence and of the geographical dispersion of the disease.

In all endemic countries, the notification networks themselves were seriously deficient. Usually, health units were supposed to provide weekly or monthly summaries of the number of patients seen, but smallpox was often only one of 25–50 different diseases that they were expected to report. Poorly supervised, overworked health staff customarily devoted little time to the preparation of lengthy reports which rarely led to any action being taken. Some regularly submitted reports to higher authorities but many did so only occasionally. In intermediate administrative units—such as states or provinces—and at national level, data were usually received and tabulated, often after extended delays, by clerical personnel whose responsibility was limited to ensuring that the data were entered accurately. Little notice was taken of whether all units reported or when they did so, and because the data were rarely used in programme operations, there was little incentive to improve the system.

All countries were expected to send to WHO weekly reports of cases of the so-called quarantinable diseases (smallpox, cholera, plague, yellow fever and typhus), and to indicate the areas in which they had occurred. Such routine reporting had been the practice since the adoption of the International Sanitary Convention of 1926, when receipt and publication of the information was the responsibility of the Health Organisation of the League of Nations, a function assumed by WHO on its foundation.

In WHO, in 1967, the receipt and tabulation of data on the quarantinable diseases was the responsibility of the International Quarantine unit, which later became the Epidemiological Surveillance and Quarantine Unit and in 1971 was renamed the unit for the Epidemiological Surveillance of Communicable Diseases; for convenience, it is referred to below simply as the "WHO quarantine unit". Reports were received direct from the countries concerned rather than through the WHO regional offices, and indicated the number of reported cases in each administrative unit, or "local area" as it was called, such as a district or county. The reports also specified which of the local areas were newly infected and which could be declared free of the disease. Each week a lengthy list of the existing and newly infected local areas in each country was published in the *Weekly epidemiological record* for each of the quarantinable diseases. In theory, this enabled quarantine officers and others concerned to determine whether or not a traveller had been in an area in which one of the diseases was present and to take appropriate measures. In practice, most health authorities recognized that reporting everywhere was deficient and usually considered the whole of a country to be infected if infection was present in any of its local areas.

The WHO quarantine unit also tabulated the number of cases reported. The data so compiled were considered to be the provisional official totals of cases, pending later receipt of annual reports from national governments. Such annual reports, when compiled and published some 3–4 years later by the WHO Division of Health Statistics, constituted the final authoritative international record of disease incidence. No attempt was made to reconcile the data in the provisional reports with those in the annual reports, and national authorities were seldom questioned as to the accuracy of the information provided.

Changes in the International Data Collection System

The inadequacy of the routine data collection system for smallpox cases had been recognized in 1967 but not until much later did it become apparent just how inadequate it was. Smallpox eradication programme staff had assumed that, because smallpox was one of the principal diseases subject to international quarantine agreements and because most infected countries submitted weekly reports, albeit after long delays, it was one of the better-reported diseases. However, field investigations soon showed that not more than 1 case in 20 was being notified. Later, through facial pockmark surveys, it became apparent that probably not more than 1 case in 100 was being reported and, in some countries, such as Ethiopia, perhaps 1 in 1000. Despite the incompleteness of reporting, however, the notified data proved to be important from the beginning of the programme for decisions about priorities and resource allocations and for assessing progress; ultimately, they were essential in determining that transmission had been interrupted and in certifying that eradication had been achieved.

Efforts to improve the system began with the initiation of the Intensified Programme. Deficiencies became apparent almost immediately when WHO staff attached to national smallpox eradication programmes cited national data which differed from those reported to the WHO quarantine unit. When efforts were made to reconcile the two sets of figures, it was discovered that, in many ministries of health, there were two sets of data, one compiled by a statistical unit and one by smallpox eradication programme staff. The statistical unit's data were taken from routine reports submitted by states and provinces, while those of the smallpox eradication programme office were often revised to take into account additional cases discovered during field investigations, reports obtained by the staff from states or provinces which had failed to file reports with the statistical office, and information on reported cases which had been mistakenly diagnosed. It was usually of no importance to national eradication programme staff whether the statistical unit's data differed from theirs or not, since such differences had no bearing on their operations.

Through correspondence with the countries and discussions with the WHO quarantine unit, WHO smallpox eradication staff sought to obtain the most complete national data available. In some instances, it was possible to obtain revised national figures extending over many months or several years, which usually showed much larger numbers of cases than those reported by the national statistical unit. The WHO quarantine unit did not take cognizance of such information because its responsibility was to compile only the current data officially reported to WHO and to maintain the registry of local infected areas. For the first three years of the Intensified Programme, two sets of data were maintained at WHO on smallpox incidence during the current and immediately preceding years. Depending on the WHO publication, sometimes one and sometimes the other set of data was used, but smallpox surveillance reports always used Smallpox Eradication unit data. In 1969, it was agreed that the Smallpox Eradication unit would assume the responsibility for all current data on smallpox cases and infected local areas, a procedure which reduced confusion and conserved manpower.

Meanwhile, through personal contact, correspondence and the publication of summaries of the smallpox situation in the *Weekly epidemiological record*, governments were urged to report more promptly and gradually began to do so. However, even as late as May 1970, reports from 5 countries were more than 4 weeks overdue and not until 1972 were reports received promptly from all the states of India (see Chapter 15). By the end of 1972, however, few reports from countries were delayed by as much as 2 weeks.

In 1970, another question arose in WHO Headquarters regarding what should constitute the authoritative international record of smallpox incidence. In that year, staff in the Division of Health Statistics observed that the numbers of smallpox cases in governments' annual summaries of disease incidence (a third data set) did not always agree with the data compiled by the Smallpox Eradication unit. Upon investigation, it was found that the differences usually reflected the fact that two sets of data had been compiled nationally. In other instances, clerical errors had been made in the annual summaries submitted, sometimes resulting, for example, in smallpox cases being reported by countries remote from endemic areas and with no known importations. These errors were quickly corrected by the governments concerned when they were

Table 10.10. World total of smallpox cases as recorded in April 1967[a] and as revised in 1987

Date recorded or revised	1959	1960	1961	1962	1963	1964	1965	1966
April 1967[a]	81 444	60 956	85 594	82 413	99 599	49 956	64 321	65 512
1987 revision	96 571	67 127	90 588	98 759	133 791	77 295	112 228	92 650
Percentage increase	19	10	6	20	34	55	74	41

[a] Unpublished World Health Assembly document A20/P&B/7.

brought to their attention but such data had been accepted without question in previous years. Towards the end of 1970, it was decided that the data compiled by the Smallpox Eradication unit, based on what it considered to be the most accurate national data, should be used in WHO publications. Thus, what had once been three different sets of smallpox data in WHO became one.

The possible suppression of reports of smallpox cases by national authorities was a continuing concern, although it did not happen often. Such suppression was most marked in western Asian countries and resulted, in part, from the adverse consequences of reporting cholera cases during a recent pandemic. These reports had induced other governments to impose unwarranted barriers to trade and travel which had caused serious economic losses. Some feared that reports of smallpox might result in similar measures being taken and therefore suppressed them. Cases of smallpox, especially when they were numerous, were not easy to conceal, however, and WHO learnt about them from many sources, including embassies, travellers and persons working in international organizations. All rumours of outbreaks were followed up by WHO by telex and by correspondence and sometimes by personal visits. Even when it was certain that smallpox was present, publication of the information without official government approval was diplomatically impossible. The suppression of reports had 2 adverse consequences: it jeopardized the credibility of the programme and the eventual acceptance of global eradication; and it made it difficult for the countries concerned to mobilize health resources and community support in order to control the outbreaks. Although most health authorities eventually cooperated in reporting, 4 did not acknowledge the existence of cases until many months or years later, and 3 eventually experienced major epidemics. These are discussed in Chapter 22 (Somalia) and Chapter 23 (Iran, Iraq and the Syrian Arab Republic).

Throughout the programme, national totals of smallpox cases were corrected whenever better information became available so as to reflect more accurately the actual incidence. Data for 1967–1977 were most carefully scrutinized, but changes were also made in data for a number of years preceding 1967. For example, the data presented in this book show global totals for smallpox cases between 1959 and 1966 substantially greater than those in the report (prepared in April 1967) submitted by the Director-General to the Twentieth World Health Assembly. The totals for the years 1959–1962 are 6–20% greater and those for 1963–1966 are 34–74% greater (Table 10.10). The larger discrepancies after 1963 reflect the fact that smallpox eradication staff in most countries reviewed and revised national and state or provincial data only from 1963 or 1964 onwards.

International Surveillance Reports

A basic precept of surveillance is, as has already been quoted from the WHO Handbook, the "widespread dissemination of the compiled and interpreted data to principal reporting sources and to others concerned with disease control activities". Accordingly, the first of what were intended to be quarterly international surveillance reports was issued by the Smallpox Eradication unit as a mimeographed document in September 1967. It was sent to some 200 persons, principally WHO staff concerned with smallpox eradication and national programme directors. A second report was issued in December 1967 and a third prepared in March 1968. Distribution of the third report was stopped, however, by senior WHO management staff, who believed that there were too many WHO reports and therefore decided to suspend most of them pending a

full review of WHO's publication policies. Eventually, it was decided that smallpox surveillance reports should be discontinued.

The coordination of a global programme was difficult enough, but without some mechanism for disseminating information on its status and the progress being made, the task appeared impossible. The matter was discussed in WHO in a series of difficult meetings extending over 8 weeks, and it was finally decided that a brief report on smallpox could be inserted periodically into the *Weekly epidemiological record*. From May 1968 onwards, such reports were published every 2–3 weeks.

Use of the *Weekly epidemiological record* had both advantages and disadvantages. The main advantage was that it was a well-established periodical with a circulation of some 5000 copies which reached a far larger audience than was possible with the mimeographed report. The disadvantage was that it published only epidemiological data, to the exclusion of other information which the smallpox eradication programme needed to have disseminated, such as the results of tests on the bifurcated needle and techniques for its use, and reports of the deliberations of relevant expert committees and scientific groups. Moreover, the periodical was normally sent by surface mail and not all WHO and national smallpox eradication programme staff had access to it. To solve these problems, it was agreed that additional copies of the smallpox surveillance section of the *Weekly epidemiological record* would be printed and sent by air mail, together with other special reports dealing with smallpox, to the 150–200 persons concerned with the programme. Thus began the practice of a special mailing every 2–3 weeks to all WHO and senior national smallpox eradication programme staff, a practice which ensured more rapid delivery than the traditional channels of communication through the regional offices. The WHO/SE, SE and SME series of documents listed with the references at the end of this book constituted most of the papers so distributed. Accounts by field staff were seldom prepared without considerable persuasion because, for many, English was not their mother tongue and few were experienced in writing papers for publication. A promise that smallpox eradication programme staff would edit all suitable papers increased the number submitted. Although the editorial burden was staggering, the papers proved invaluable in documenting useful observations made in the course of the programme and in fostering evolutionary change.

Following the incorporation of the smallpox surveillance reports into the *Weekly epidemiological record*, its editor, Dr Ian Carter, began to transform the publication itself. Once unkindly referred to as "the laundry list of infected local areas", the periodical gradually became a substantive document dealing with many diseases and reaching an increasingly wider public. With time, the smallpox surveillance reports gradually increased in length and frequently appeared on the first page, but the prominence given to smallpox eradication troubled the responsible Assistant Director-General, who felt that other important disease problems were not receiving sufficient attention. He therefore directed that the smallpox reports should be relegated more often to the inside pages. Thereafter, by tacit agreement, the smallpox surveillance report appeared on the front page of the *Weekly epidemiological record* only twice a year, when the semi-annual summaries were published.

RESEARCH

In 1967, few administrators or scientists believed that additional research was needed or would contribute to the achievement of smallpox eradication. This was understandable. A smallpox vaccine had been available and in use for more than 150 years and the commercial production of a thermostable vaccine had been perfected. The epidemiology of the disease under many different circumstances and in many countries had been described and the feasibility of eradication had been demonstrated in a number of developing countries. The basic task, as most saw it, was administrative—primarily that of organizing programmes to deliver vaccine to the population of the endemic countries. The attitude towards research was similar to that which had prevailed when global malaria eradication began in 1955. In that programme, research had been largely abandoned until 10 years later, when, with the programme progressing poorly, it was recognized that additional tools and different strategies were required. By then, however, competent and experienced research staff had turned to other fields. It was an important

lesson, and one which those in the Smallpox Eradication unit believed should be heeded.

In 1967, little smallpox research was in progress, and only US$20 000 were allocated in the WHO budget for the support of such research. With so few resources and with only 4 medical officers in the Smallpox Eradication unit in Geneva, WHO could not undertake a comprehensive, well-organized research programme. However, it was hoped that field staff might be able to make significant contributions and, to stimulate their interest, some 20 areas requiring research were identified in the WHO Handbook. In consequence, many field staff undertook and participated in a wide range of important studies from the beginning of the programme.

One research area was of paramount importance—to establish with certainty whether there was any natural reservoir of variola virus. Since yellow fever eradication had been thwarted by the unexpected discovery of an animal reservoir, and in the light of the suggestions then being made that there might be a simian reservoir of malaria, the question naturally arose whether there might also be an unrecognized natural reservoir of smallpox. This question was dealt with in a series of planned studies involving many different investigators and laboratories.

Substantial amounts were eventually spent in support of research by many laboratories and, although no quantitative data are available, they were far greater than the sums provided by WHO. Of especial note are the contributions of CDC in Atlanta, the Moscow Research Institute for Viral Preparations, the National Institute of Health in Japan, the Department of Virology of St Mary's Hospital Medical School in London, the National Institute of Public Health in the Netherlands, Wyeth Laboratories in the USA, the Calcutta Institute of Tropical Medicine in India, the Public Health Institute in Bangladesh, the Pakistan Medical Research Centre in Lahore and the University of Maryland School of Medicine in Baltimore, whose scientists worked in Pakistan.

In retrospect, it is unlikely that the global eradication of smallpox would have been achieved without the broader understanding of smallpox, its virology and epidemiology, which the research conducted after 1967 provided. The results of such research include: the redefinition of the epidemiology of smallpox and because of this, a change in the strategy so as to place increased emphasis on surveillance and containment; an improved understanding of the efficacy and duration of vaccinial immunity and, as a result, changes in practices pertaining to revaccination; a great improvement in vaccine production and testing procedures; the development of a new technique of vaccination, employing a new instrument; the genetic mapping of variola and vaccinia viruses to provide new insights into the relationships of the orthopoxviruses; the discovery and characterization of human monkeypox; and the development of sample survey techniques.

The research programmes and the observations made are described in detail in the appropriate chapters of this book. For this reason, only the highlights of some of them are described here so as to place them in the context of the development of the global programme.

A Natural Reservoir of Smallpox

From 1967 onwards, attention was focused on determining whether smallpox virus could persist in nature outside the human being. If smallpox were found to persist in an enzootic state, or if there were a closely related animal orthopoxvirus which could infect humans and whose transmission could be sustained in man, it was unlikely that smallpox could be eradicated. No less important was the question of how long variola virus could persist in nature, since this, too, had implications for the possible recurrence and re-establishment of infection in areas in which transmission had been interrupted. These problems are discussed in Chapters 2, 29 and 30.

The first review of the available data dealing with a possible animal reservoir of variola virus was published by Arita & Henderson (1968). They reasoned that, if there were a natural reservoir of variola virus, non-human primates were important candidates. As is discussed in the paper, a few reports had suggested that smallpox outbreaks did occur naturally in primates, but most of them dated from the 19th century. In view of the extent of endemic smallpox in countries in which primates were found and the paucity of reports of possible outbreaks in the present century, it seemed unlikely that primates really were a reservoir, but confirmation was

required. Also of interest was the closely related monkeypox virus, first described by Magnus et al. (1959) after an outbreak among a colony of laboratory primates and subsequently reported in 3 other laboratories. No human infection had occurred, but because adults in close contact with the animals were few and probably well vaccinated, no conclusions could be drawn about the possible infectivity of the virus for man. To study the matter further, Arita, in 1967, conducted a survey of 26 biological institutions which handled large numbers of primates to ascertain whether other, unpublished, outbreaks had occurred, to discover the circumstances associated with such outbreaks and to find out whether there had also been human infections. Five other outbreaks among primates came to light but no human cases. Almost all the illnesses occurred in Asian species and were clinically similar to those observed when primates were experimentally infected with smallpox.

To consider the problem of monkeypox and to develop a research agenda, a meeting of investigators from 6 laboratories (the Informal Group on Monkeypox and Related Viruses) was convened by WHO in March 1969 in Moscow. Thereafter, the investigators met every 2 years to plan a wide range of studies on the experimental infections of primates and other mammals with variola and monkeypox viruses and serological surveys of primates in Africa and Malaysia. New impetus to the efforts was given by the discovery of the first human monkeypox cases in 1970, and the working group was expanded to include epidemiologists and mammalogists. Subsequently, special field surveys were initiated to define the problem; these continued up to 1986 (see Chapter 29). They provided important substantiating evidence that no mammalian reservoir of smallpox existed and that monkeypox, confined to villagers in the tropical rain forest, could not be maintained by person-to-person transmission.

A second problem was to determine whether variola virus could persist in nature on fomites such as cloth or as scabs, and cause infection in man many months or even years later. That this was a cause for concern had been suggested in studies by investigators in the Netherlands, who demonstrated the survival of variola virus in scabs for as long as 13 years (Wolff & Croon, 1968). Whether the virus was of sufficiently high titre or in a form such that man could be infected was unknown. The possible persistence of variola virus in nature was also suggested by anecdotal accounts, dating from previous centuries, of cases and outbreaks following the exhumation of the body of a person who had died of smallpox and of cases said to have occurred in newly reoccupied houses in which a smallpox patient had died months or years before. The validity of these observations was uncertain because all had been reported from areas in which smallpox was then widely endemic. Also of concern were variolators in Africa and Asia, who were known to collect and retain scabs and pustular material for periods of a year or more.

To determine the possible risk of the persistence of viable variola virus under field conditions required many different epidemiological and laboratory studies. Laboratories in Bangladesh and India undertook to determine the duration of the viability of variola virus under different conditions of temperature and humidity. Epidemiologists were instructed to document with care the source of infection of cases, especially those in which there was a possibility of exposure to virus which had persisted in the environment. Special efforts were made to determine the source of infection of outbreaks in all countries thought to be free of smallpox. Variolators were contacted and questioned in detail about their experiences in retaining smallpox material, and variolation material was obtained from them for titration in the laboratory. The results of these studies are described in Chapters 2 and 30. Ultimately, it became clear that, even under favourable conditions of low temperature and humidity, the virus did not survive for more than a few days or weeks in a form which could induce infection, unless inoculated, as in variolation. Even in this case, variolators reported that they had difficulty in inducing infection with material retained for longer than a year.

Epidemiological Observations

Of the many epidemiological observations, the most important were those which indicated that surveillance and containment should be accorded a much higher priority than had initially been appreciated. The first and most comprehensive of the field studies were those conducted in Pakistan and Bangladesh (then East Pakistan) during 1965–1968

and directed by scientists from the University of Maryland, USA, and the Pakistan Medical Research Council (see Chapters 4 and 14). In careful studies of the characteristics of the spread of smallpox, they showed that, even in highly infected areas, cases tended to occur in clusters rather than being widely disseminated, and that the disease spread less rapidly and less easily than was commonly believed and only through close personal contact. Moreover, during periods of seasonally low transmission, they found few continuing chains of smallpox transmission, mainly in urban areas. These characteristics suggested that the spread of smallpox could be more rapidly interrupted if greater emphasis were placed on the discovery of cases and the containment of outbreaks, especially during the season when transmission was at a low level and in urban areas. Observations in eastern Nigeria in 1967, in India in 1968, and in Brazil and Indonesia in 1969 confirmed the practicability of this approach. These observations were made known to all smallpox eradication programme field staff, but the basic concepts of surveillance and containment were slow to be accepted, having to be rediscovered and/or demonstrated in special programmes in most areas before they were incorporated into programmes.

Many other studies and observations arising from field programmes led to changes in strategy and operations (see Chapters 4 and 12–22). Among these were studies which showed that variola minor could persist for long periods among small nomadic groups, necessitating special surveillance procedures; that women in Afghanistan, confined to their houses by the practice of purdah, were mostly immune owing to a previous attack of the disease or to vaccination and that special vaccination programmes for them were unnecessary; and that the airborne transmission of variola virus over a distance was possible but only under exceptional circumstances and within buildings and so was not of concern. Methods were developed by which to estimate the incidence of smallpox in previous years, and special studies documented the frequency of persistence of facial pockmarks, observations which were important in deciding on the strategy for certification.

Few investigations were undertaken which required substantial laboratory support, partly because many of the studies required no more than physical observations of lesions or scars, and partly because few laboratories were equipped to process large numbers of specimens. Studies which did involve laboratory support were conducted in Bangladesh, India, Somalia and Zaire and concerned the behaviour of other animal poxviruses (see Chapter 29) and the pharyngeal excretion of variola virus among contacts of patients (see Chapter 4).

Vaccination Practices

Through research, not only did better vaccination instruments come into universal use but other vaccination practices also changed. Policies with regard to the youngest age for vaccination and the recommended frequency of revaccinations were changed. In most endemic countries, in 1967, primary vaccination was not given until the child had reached 3–12 months of age, and revaccination was performed every 3–5 years. The vaccination of neonates, however, had long been known to be a safe and effective practice and, in fact, had become a standard procedure in some countries of eastern Asia (Urner, 1927; Moodie & Cheng, 1962). Dr A. R. Rao's confirmation of these observations, in a WHO-supported programme in southern India, served to encourage wider acceptance of the practice, which made it easier to achieve higher levels of vaccination coverage during mass vaccination campaigns and enabled very young children to be protected during outbreak containment. That immunity following vaccination might be far more long-lasting than had been thought was suggested by field observations which showed that, even in well-vaccinated populations, 80–95% of cases occurred among those who had never been vaccinated. More precise measurements of vaccine efficacy subsequently confirmed that high levels of immunity continued for at least 10–20 years. These findings, documented early in the programme, led to a shift in the emphasis of vaccination campaigns from an effort to reach the entire population to approaches which would ensure that everyone had received primary vaccination at some time.

Vaccine Production and Testing

In 1967, much was known about commercial methods for the production of freeze-dried smallpox vaccine and a production manual

was issued by WHO in 1968 (SE/68.3 Rev.2). Nevertheless, several studies were undertaken to examine certain aspects of the process, such as the optimum day for harvest to ensure maximum virus yield, the yields of virus produced by different strains, and alternative methods of purifying the vaccine and reducing bacterial content (see Chapter 11). Testing procedures were thought to have been standardized, but when different laboratories obtained quite different results on testing the same batches of vaccine, studies showed that slight but previously acceptable variations in technique were responsible; these were corrected. Although collaboration among potentially competing production laboratories is uncommon, this was not the case in the smallpox eradication programme. Laboratories in Canada, Czechoslovakia, the Netherlands, the USSR and the USA cooperated and shared information in solving problems, and their findings were communicated to all production laboratories.

Characterization of the Orthopoxviruses

An examination of the similarities and differences between variola virus and other orthopoxviruses was important in assessing the likelihood that such a virus might, in some manner, mutate to a form whose virulence and transmissibility were such that infection could be sustained in man. Support for studies aimed at a more precise characterization of orthopoxviruses was provided by WHO to laboratories in London and Birmingham (England), Atlanta (USA), Tokyo (Japan) and Moscow (USSR), each of which committed substantial additional resources of its own. The importance of these studies increased with the discovery, in the early 1970s, in the Netherlands and in the USSR, of virus strains apparently isolated from animals and having characteristics indistinguishable from those of variola virus. Until the discovery of restriction endonucleases, which enabled the DNA structure of viral strains to be analysed, these analyses relied on biological markers, such as growth properties in different animals and cells and the optimum temperature for growth. The techniques were complex and time-consuming and the interpretation of the results was often uncertain. Ultimately, restriction endonuclease analyses of viral DNA proved of the greatest value. The isolates of variola-like viruses obtained from animals in the Netherlands and the USSR were eventually shown to have been laboratory contaminants (see Chapter 29) and genetic analysis showed that it was highly unlikely that any of the large number of animal orthopoxviruses could be transformed by one or even several mutational steps into a virus which resembled variola virus.

Summary

Even from this brief recapitulation, it is apparent that the epidemiological and laboratory research stimulated and coordinated by WHO contributed materially to the achievement of smallpox eradication. The effort was not, overall, a wholly integrated and comprehensively planned effort and was only modestly supported by WHO funds, but it was remarkably well directed towards finding solutions to operational questions and needs. Of signal importance was the ready cooperation of the investigators and their willingness to make available their papers and their data before publication. This, in turn, permitted the earliest possible application of new findings.

STRATEGIES AND TACTICS IN THE EXECUTION OF NATIONAL PROGRAMMES

Introduction

A survey of the approaches adopted in national vaccination campaigns and in surveillance and containment measures is provided in this section as an introduction to Chapters 12–22, which describe field operations in the various countries. The principles and practices were common to most but many aspects of the structure and method of operation of each national programme were unique, since each had to be adapted to the prevailing administrative, social, demographic and geographical conditions and each changed with time in response to experience and needs.

As has previously been described, the basic strategy for national programmes called for 2 different activities: (1) mass vaccination campaigns, assessed for both coverage and take rates by special teams; and (2) surveillance and containment of outbreaks. As infor-

mation accumulated on the extent of vaccinial immunity and the epidemiology of smallpox in the different countries, it became apparent that mass vaccination campaigns, particularly in Asia, were less important than the discovery and containment of outbreaks. Vaccinial immunity was found to be generally higher in most countries than had been expected and, in some countries, smallpox cases were so few that a comparatively simple surveillance and containment programme could serve to interrupt transmission.

Because mass vaccination campaigns were the traditional control method and were most readily accepted by national authorities, all endemic countries and many of those adjacent to them conducted such campaigns. While perhaps unnecessary in some areas, they served an important additional function in that vaccination teams, moving from village to village, were able to detect unreported cases of smallpox or to confirm its absence.

Surveillance–containment programmes, however, were frequently slow to begin, because the logistics of mass vaccination campaigns were so demanding and the techniques unfamiliar. Some programmes, adopting the tactics used for malaria eradication, deliberately delayed the commencement of surveillance until mass vaccination had been completed, an activity which they equated with the "attack phase" of the malaria programme. It was not always easy to persuade national programme staff and WHO smallpox eradication advisers that surveillance–containment operations should begin immediately and be accorded as high a priority as mass vaccination.

The importance of surveillance and containment was emphasized in discussions at the World Health Assembly and by Health Assembly resolutions in 1968 and 1969, and again by an explicit resolution of the Executive Board (EB45.R20), subsequently endorsed by the Twenty-third World Health Assembly (1970), in which the Board requested "all countries to take appropriate steps to improve further case-reporting and to adopt as an objective the immediate investigation and containment of all reported cases and outbreaks of smallpox from 1970 onwards" (World Health Organization, 1973a). Much effort was devoted to accomplishing this objective and demonstration-type programmes were organized to encourage it. Its importance was further reinforced in numerous publications and communications. From 1969 onwards, smallpox eradication staff at WHO Headquarters recommended that surveillance–containment measures should be given priority over mass vaccination but because change was slow to come, they proposed in 1972 that all resources should be directed to surveillance–containment and that mass vaccination should be stopped. Although this proposal did not reduce the interest in mass vaccination on the part of most national authorities, it ultimately served to focus sufficient attention on surveillance and containment to permit the development of satisfactory programmes. To suggest that mass vaccination was unnecessary in any circumstances was recognized to be extreme and simplistic but it seemed necessary to do so at the time in order to alter national strategies. This was not without certain repercussions, however. By the time the emergency programme was introduced in Somalia in 1977, the principle of surveillance–containment had acquired a doctrinal quality and some WHO smallpox eradication advisers argued that it was heretical to conduct mass vaccination campaigns in any area, whatever the need (see Chapter 22).

The most important factors determining the success of all programmes were the quality of senior staff at the national level and their willingness to go into the field to see for themselves what progress was being made, to find solutions to problems and, by their example, to encourage lower-level supervisors to do likewise. In most countries, it was both traditional and accepted for supervisors, even at the lowest administrative levels, to remain in their offices. Many considered it demeaning to leave them, and those who wished to do so frequently lacked the necessary authority or transport. Supervision was customarily provided through verbal orders and written directives, and the results of programmes were assessed, if at all, through written reports, often of dubious veracity. In the smallpox eradication programmes, the supervisors were provided with transport, and WHO staff and consultants, by their example, played an important role in helping to change traditional patterns. Frequently, it was found that national and WHO smallpox eradication programme supervisors were almost the only supervisory staff to visit health programmes in the field or district centres and dispensaries. This type of frequent contact between supervisors and field personnel not only served to

resolve problems more rapidly and to redirect activities more efficiently but also proved invaluable in sustaining morale and interest.

In the following pages, the general practices followed in mass vaccination campaigns are discussed first, followed by those in the surveillance–containment programmes.

Mass Vaccination Campaigns

Objectives

Before 1967, the smallpox eradication strategy relied entirely on mass vaccination in the belief that, when the proportion of susceptible persons in the population had been substantially reduced, transmission would cease. Until 1964, it had been assumed that this would occur when 80% of the population had been successfully vaccinated within a period of 4–5 years (World Health Organization, 1959b), an arbitrary figure with no scientific basis. Between 1959 and 1966, mass vaccination campaigns succeeded in eliminating smallpox in a number of countries, but whether 80% of the population had been successfully vaccinated is unknown as little attempt was made to assess the results of the campaigns and knowledge of the numbers of vaccinations performed is of little value because most of the vaccine used was thermolabile and lacked potency, so that many vaccinations were undoubtedly unsuccessful.

The WHO Expert Committee on Smallpox (1964) declared the figure of 80% to be insufficient and recommended that the goal should be to vaccinate 100% of the population. The only basis for this recommendation was the observation in India that smallpox persisted in some areas despite vaccinations which, in the numbers reported, were equivalent to 80% or more of the population. The Committee, however, ignored the information from field studies in India itself (later critically examined by Gelfand, 1966), which showed that the proportion *successfully* vaccinated fell far short of 80% because of the use of subpotent vaccines and the frequent revaccination of the most easily accessible groups. The proposition that smallpox could be eliminated by successfully vaccinating 80% of the population was thus discarded but on scientific evidence just as inadequate as that on which it had originally been based.

The WHO Handbook also recommended that mass vaccination campaigns should aim at successfully vaccinating 80% of the population. The figure was an arbitrary one, intended only to indicate what could reasonably be expected in a well-conducted programme.

One can only speculate as to how many countries might have succeeded in interrupting transmission simply with an effective mass vaccination campaign reaching 80% or more of the population. However, from the authors' review of programmes conducted after 1967, it would appear that mass vaccination alone resulted, or probably would have resulted, in the elimination of smallpox in South America and most African countries but not in the densely populated countries of Bangladesh, India, Indonesia and Pakistan. Even in America and Africa, however, surveillance programmes were necessary, to provide the basis on which to be able to certify that transmission had been interrupted.

Administration

The mass vaccination campaigns were conducted by national health staff, usually with technical advice and material assistance from WHO and other agencies. A full-time programme director and unit were usually made responsible for the programme; in the larger countries, special units were also created at state or provincial levels. The programme staff were an integral part of the health ministry and worked with existing health service units, coordinating their activities whenever possible with those of other special programmes, such as those for BCG vaccination, malaria eradication and leprosy and yaws control. Their salaries were paid by the respective governments, although in some cases WHO supplemented the salaries of some senior staff to enable them to work full time in the programme. In most countries, international assistance bore the costs of all supplies and equipment as well as living allowances and travel costs for surveillance teams and the costs of petrol and vehicle repairs. After 1973, when many temporary workers began to be employed to intensify programmes in the remaining endemic countries of Asia and eastern Africa, their salaries were also met by funds from international assistance.

Preparations

The necessary preparations for a vaccination campaign could be completed within a matter

of a few weeks or a month or two, but most programmes did not begin until 6–18 months after an agreement had been signed between the government concerned and WHO. The length of the delay was usually determined by the time required to deliver the necessary vehicles, but also sometimes by a lag in the allocation of government funds for salaries. During this period, information regarding the past history of smallpox in the country was obtained, demographic data and maps were collected, and staff were selected and trained. As has already been noted, the compilation of the smallpox data available from state and provincial offices and other sources often revealed more cases than those recorded in statistical offices and officially reported to WHO. The compilation of such data made better baseline information available for use in deciding on priority areas for vaccination and in gauging subsequent progress. Except in areas in which malaria eradication programmes had been conducted, the existing maps were generally inaccurate and demographic data often at considerable variance with what programme operations later revealed. Nevertheless, such maps and data were useful as points of departure, changes being made in them as the programme progressed and additional information was obtained.

The supervisors and vaccinators for the programme were mainly health personnel who had previously been engaged in smallpox vaccination or who had been transferred from other field programmes, such as those for BCG vaccination or leprosy or yaws control, which for one reason or another had all but ceased operations. The numbers of health personnel required for the programme were not large and, because underutilization of health personnel in most endemic countries was common, it was seldom necessary for the government to hire additional staff to serve as vaccinators or supervisors. Those who served as vaccinators had usually had at least 6–8 years of education and were sufficiently literate to use forms for recording data. Illiterate vaccinators were also successfully used, especially after 1973, when the programmes were greatly intensified. Supervisors, in general, had had at least 10–12 years of education and had sometimes received additional training in the operation of health programmes.

For most smallpox eradication programmes, special training lasting 1–4 weeks served to familiarize the staff with the nature of the programme and with their duties and responsibilities. In all but the largest countries staff numbers were sufficiently small to permit close and continuous contact between the senior national staff, the field supervisors and the vaccinators, thus facilitating supervision and a progressive improvement in performance. In larger programmes, and where the staff were widely dispersed, supervision was more difficult and the programmes were generally less effective. During the course of the programme in India over the period 1974–1977, however, an effective method was found for the supervision of large numbers of widely dispersed staff (Brilliant, 1985). A 1-day meeting of senior staff and supervisors was held every month to review performance, progress, strategy and problems. Subsequently, the supervisors and junior supervisors held a similar 1-day meeting and, finally, junior supervisors and vaccinators reviewed the progress in an area served by a health centre. Although the national programme involved more than 100 000 workers, it proved feasible to supervise activities closely and to modify and continually redirect the programme effectively.

Special activities were undertaken to interest and involve health staff based in the outpatient departments of hospitals, in health centres and in similar facilities. In group meetings and during field travel, smallpox eradication programme staff regularly discussed with them the nature and objectives of the programme, emphasized the need to report smallpox cases, and provided supplies and instruction in the proper storage and use of freeze-dried vaccine. Experience showed, however, that in most countries such health staff failed to report cases regularly, usually vaccinated very few of those who attended clinics and seldom undertook to vaccinate people living in nearby houses or villages.

Provision was made for the cold storage of vaccine (at 0–4°C) in the capital city, sometimes in refrigerators belonging to the programme and sometimes in other units used for the refrigeration of meat or vegetables and fruit. Vaccine was also kept at state and district centres in ordinary refrigerators, which were often provided by the programme, the number and location depending on the difficulties of travel and the availability of transport. The distribution system was designed so that vaccine would not be exposed to ambient temperatures for more

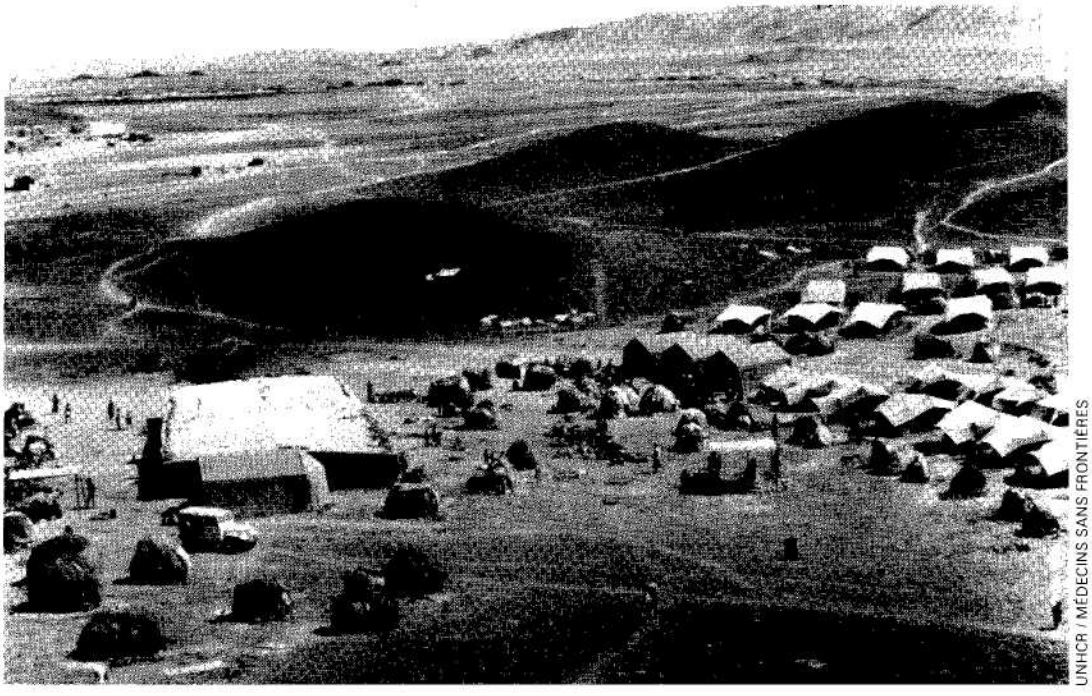

Plate 10.25. Refugee camp for Ethiopians in Djibouti. Special vaccination campaigns were regularly conducted in such camps to prevent outbreaks of smallpox.

than 30 days. In most programmes, however, the maintenance of an effective "cold chain" proved difficult and was often unsatisfactory, usually because of the mechanical failure of refrigerators, interruptions in electrical supply or lack of kerosene. Not infrequently, the vaccine was exposed to ambient temperatures for more than 30 days but because of the high titre and the stability of most vaccines, primary vaccinations were usually successful in 95% or more of the subjects concerned even when the vaccine had been exposed to such temperatures for as long as 6–9 months. Despite failures in the distribution system, unsuccessful vaccinations with properly manufactured vaccine were uncommon after 1967.

Special efforts were made to ensure that vaccination teams and health units always had on hand an adequate supply of vaccine and bifurcated needles. The instructions therefore called for orders to be submitted in advance so that supplies could be replenished well before they ran out, but the system rarely worked well; most units and many countries waited until supplies were exhausted before ordering more. The reserve supplies of vaccine and needles in Geneva, from which deliveries could be made within 48–72 hours, helped to overcome this difficulty.

Finally, health education materials, such as posters and brochures, radio messages and other media material, were prepared. Although these were used in all programmes, such studies as were done showed that individual discussions with villagers by team leaders, vaccinators or search workers were much more effective in obtaining cooperation and participation.

After the necessary equipment had been assembled and personnel recruited, pilot projects were conducted in most countries. Because mass vaccination was comparatively simple and often familiar, they seldom lasted more than a few weeks or months and were designed primarily for training purposes rather than to test alternative methodologies.

Execution of the mass campaigns

Most mass vaccination campaigns were designed to be completed during a period of 1–3 years, depending on the size of the country and the number of personnel available. Field activities usually began in areas with the greatest population density and the

highest smallpox prevalence, thereafter moving progressively to adjoining areas. In practice, it was found best to begin the campaign in an area in which vaccination was readily accepted by the population and the logistics were simplest, and to move to more difficult areas when operational systems were well established.

Most countries used mobile vaccination teams; they varied in size but usually consisted of 2–8 persons, each team being given a vehicle. For ease of supervision and supply and to economize in transport, groups of 4–8 teams usually worked in contiguous areas under the direction of a senior health supervisor. The teams usually worked without interruption for 3 weeks, followed by 7–10 days' rest. A useful tactic, but one seldom used, was for a team of 2–3 supervisors to move from area to area and to employ local health staff to assist them. Having individuals on the team who were familiar with the people and the area and who spoke the local language enabled better vaccination coverage to be achieved. Although wider use of this approach would have been desirable, the necessary cooperation of the local health staff was usually difficult to obtain.

If work continued throughout the year, 250 days of field work were possible, but 150–200 were more usual. In some Asian countries in particular, religious and national holidays were frequent and often prolonged; in others, effective field work during the seasonal rains or the hottest months was difficult, if not impossible.

Work schedules had to take a number of factors into account. Nomads, for example, were often widely dispersed during most of the year but would congregate at certain sites to graze their animals or to assist in the harvest during a comparatively brief period. In rural areas, farmers busy in the fields avoided vaccination for fear of the resulting fever and sore arm; better coverage was therefore achieved by vaccinating during slack periods in the agricultural calendar. Special programmes had to be scheduled to vaccinate people attending religious festivals, as in the Indian subcontinent and in many Muslim countries, where thousands or even millions of people often forgathered. Programmes for refugees and migrant seasonal workers were also important. The time of vaccination also had to be taken into account. If vaccination was offered, for example, from 9 o'clock in the morning to 5 o'clock in the afternoon, large numbers of persons were usually away from their villages—in the fields, at school or at markets. Vaccination in the early morning and in the evening resulted in better coverage but such a schedule was often difficult to arrange.

Two basic approaches to mass vaccination were employed. Throughout Africa and South America, the assembly-point system, in which many subjects for vaccination gathered at a designated site, was well accepted and therefore widely employed. In Asian countries, house-to-house visits were usually made by vaccinators, although large numbers of persons were sometimes vaccinated at places such as railway stations, ferry crossings and refugee camps.

Assembly-point vaccination. At an assembly point, many people could be vaccinated by a few vaccinators in a short time if the local leaders lent their support. That support was usually sought by an "advance man" attached to the mobile teams, who visited the area concerned one or more days before the team was to arrive in order to meet the leaders, explain the nature of the programme, and enlist their support in assembling the people and controlling the crowd.

Jet injectors had been expected to be of especial value in campaigns using the assembly-point method, but their potential was seldom realized. With very well organized assembly points 1000–1500 persons an hour could be vaccinated using a jet injector but it was difficult to assemble and to vaccinate so many persons for more than a few hours each day. Because the great majority of the population lived in small, widely scattered towns and villages, the travel of the teams and the preparations at each individual site took a good deal of time. In practice, a team of 2 vaccinators using jet injectors averaged only 1500–3000 vaccinations a day, much the same as the number performed by 3 vaccinators with the much simpler bifurcated needles. Thus, in most circumstances, bifurcated needles were preferred.

The assembly-point system was usually effective in obtaining coverage rates of 80% or more wherever local support was reasonably good and even higher rates when smallpox was known to be present in the area. In rural areas, the best coverage was obtained when the assembly points were so situated that no one had to walk more than 5 kilometres, and preferably no more than 2

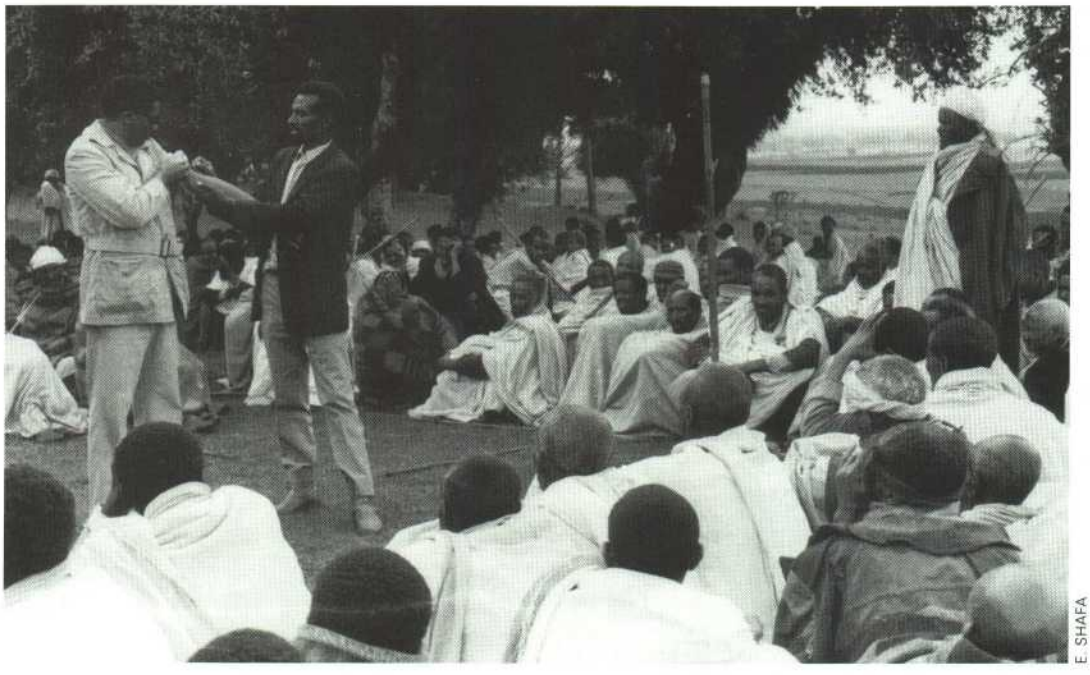

Plate 10.26. An "advance man" meets with village elders in Ethiopia to demonstrate vaccination and to explain the programme.

kilometres. Otherwise, many individuals were missed, especially children who were too young to walk very far or too old to be carried over long distances. In cities and towns, assembly points were much more closely spaced.

At the assembly points, police or village leaders were needed for crowd control, especially in areas in which the people were not accustomed to orderly queuing. Special measures also had to be taken to prevent the crowds from pressing in around the vaccinators to watch what they were doing. This was usually effected by arranging for the line of people to be vaccinated to pass through a building or between specially erected fences. The information recorded about each person vaccinated was kept to a minimum. Although some health authorities insisted initially on registering each individual by name, age, sex and place of residence, they soon discovered that this made the clerical task too burdensome and that the records compiled were of little or no value subsequently. A simple vaccination tally sheet (Plate 10.27) was commonly used to record the number of vaccinations performed by age group.

House-to-house vaccination. In most of the endemic countries of Asia, vaccinators customarily went from house to house, and this practice was continued throughout the programme. To many health officials, systematic and orderly house-to-house visits seemed more likely to ensure high levels of vaccination coverage than asking people to gather at assembly points. The method, however, had certain intrinsic drawbacks which generally resulted in a lower rate of coverage. Since fewer persons could be vaccinated in a day than at an assembly point, larger numbers of vaccinators were required. They were often more poorly paid, less strongly motivated and therefore less reliable than the assembly-point vaccinators. They were also widely dispersed, so that it was difficult to supervise them, or even to determine whether they had worked at all. The household members, since they did not know when the vaccinators were going to call, were often absent, and resistance to vaccination was more frequent when families were approached one by one in this manner than when they were part of a large crowd in the carnival type of atmosphere associated with the assembly-point method. During the global eradication programme, well-supervised house-to-house programmes were conducted in some high-risk areas of Asian countries, but were seldom assessed. In most areas, traditional practices continued, indivi-

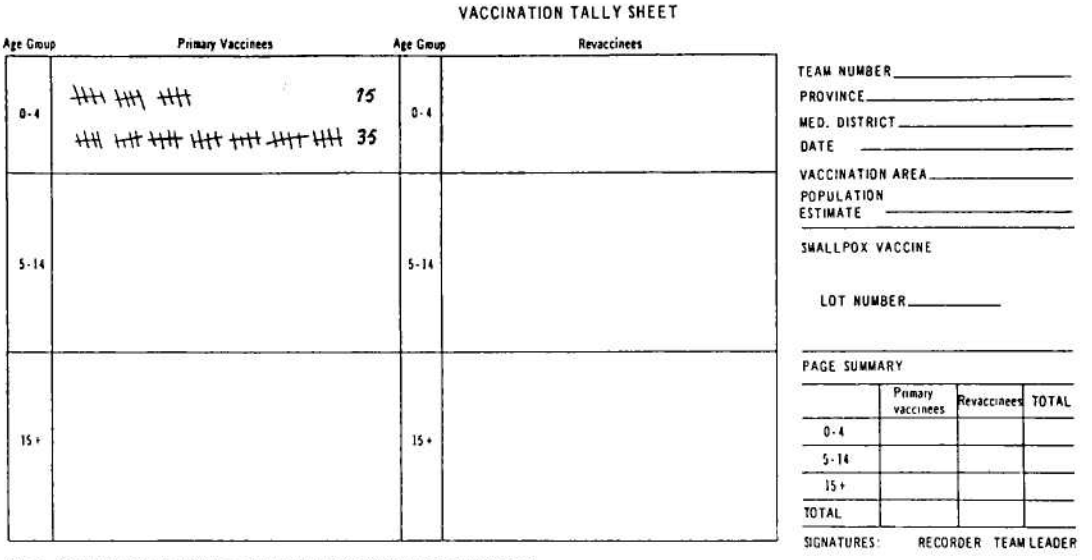

Plate 10.27. A vaccination tally sheet.

dual vaccinators being assigned responsibility for populations ranging from 5000 to 20 000 but seldom vaccinating more than 25–50 persons a day. As is described in Chapter 15, the system was costly for what it achieved.

Smallpox vaccination was generally well accepted throughout the world, even among many groups with little prior contact with health services. Groups which resisted vaccination tended to make the greatest impression on programme staff and their importance was magnified by virtue of the time and energy needed to vaccinate them. The older adults, especially women, often objected to vaccination on the grounds that they were already immune, which, in fact, most were. However, for a team trying to contain an outbreak and therefore to vaccinate everyone in the area, the older women in particular were a continual source of frustration. Some orthodox religious groups objected to vaccination on principle; on several occasions this resulted in outbreaks difficult to control. However, the numbers involved were seldom large and, through religious leaders and government officials, most people could eventually be persuaded to accept vaccination. Where variolation was practised, as in the mountainous areas of Afghanistan and Pakistan and in Benin, Togo and western Nigeria, variolators, as well as some members of the population, objected to or actually forbade vaccination. Except in the more remote areas of Pakistan, however, it was eventually possible to persuade most of them to accept it.

The largest group to resist vaccination were the Amharas of the highland plateau area of Ethiopia. To most Amharas, vaccination was unknown and neither religious leaders nor government officials were able to influence their attitudes significantly. Because only the mild variola minor form of smallpox was prevalent in the area, they did not fear the disease, even when outbreaks occurred. Many methods were used to enhance their acceptance, including that of providing drugs against other diseases after successful vaccination, but large numbers of people still refused. Fortunately, resistance was by no means universal and smallpox transmission gradually ceased in this widely dispersed population.

The simultaneous administration of one or more antigens in addition to smallpox vaccine was known to be both safe and efficacious as well as economical of transport and personnel. For this purpose, however, additional resources had to be made available for the programme and changes in operational procedures introduced. This proved possible in a number of control programmes. In

western and central Africa, measles vaccine was given to all children between 6 months and 4 years of age; in some programmes yellow fever vaccine was also given to persons of all ages; and in others, BCG vaccine was administered, usually to those aged 0–15 years. In many countries of eastern and southern Africa, both smallpox and BCG vaccines were given from the beginning of the programme and, in Afghanistan, diphtheria, pertussis and tetanus (DPT) vaccine and BCG vaccine began to be administered after smallpox transmission had been interrupted.

The question whether other vaccines might be given during the smallpox vaccination campaign did not arise in most countries, however. Up to the end of 1977, when the mass campaigns had concluded, few of the endemic countries routinely provided other vaccines because they lacked the foreign currency to buy them and little was contributed by international agencies. BCG vaccine, which UNICEF provided to a number of developing countries, was an exception. It was difficult, however, to conduct a programme for the administration of both BCG and smallpox vaccines, since the former was usually given by a more time-consuming method—intradermal injection using a syringe and needle. In Africa, vaccinators could routinely administer 500 or more smallpox vaccinations a day using bifurcated needles but only 100 or so BCG vaccinations. To give both vaccines together required either a substantial expansion in the size of the teams—difficult because of the limited transport available—or a much slower-paced programme and inevitably a delay in interrupting smallpox transmission.

To facilitate the development of combined smallpox–BCG vaccination programmes, the Smallpox Eradication unit in Geneva promoted studies of the feasibility of administering BCG vaccine with the bifurcated needle and with the jet injector. While the results obtained with the bifurcated needle were equivocal or poor, those with the jet injector were quite satisfactory. Where jet injectors were used—in Zaire and many countries of western and central Africa—the two vaccines were administered at the same time but inoculated into different arms. Except for the the constant difficulty of ensuring an adequate supply of BCG vaccine, these programmes generally functioned well.

Although an effective mass campaign for the simultaneous administration of different antigens was difficult to start, the feasibility increased as experience was gained and an administrative structure developed. It seemed logical and desirable to the WHO Smallpox Eradication unit to encourage the transformation of the programme, as smallpox began to be eliminated, into one for the provision of other antigens as well. DPT and poliomyelitis vaccines were the best candidates, as the diseases concerned posed problems in the developing countries and the vaccines were inexpensive and as yet little used. Donations of vaccine would, however, have been needed as well as additional staff at Headquarters to develop plans, mobilize resources and provide training. Efforts were made in 1970 and later to persuade senior WHO staff of the desirability of this approach, the importance of timely action increasing as one country after another became free of smallpox and began to dismantle its programme. There was, however, resistance to the development of what was seen as yet another "vertical" programme until 1974, when the Twenty-sixth World Health Assembly decided to establish the Expanded Programme on Immunization. By then, smallpox eradication had proceeded so quickly that a number of national vaccination programmes had ceased to function.

On balance, the mass vaccination campaigns were remarkably successful in most countries, high levels of acceptance and coverage being attained in almost all in 3–4 years or less. The campaigns cost most countries no more than they had been spending on their regular control measures. As the chapters on field operations will show (Chapters 12–22), the assembly-point system of vaccination did not require large numbers of national personnel and international support usually amounted to no more than US$0.07–0.25 per head of population over the course of the programme. The mass campaigns were, moreover, politically attractive, in some areas providing an important link between the people and the government—sometimes virtually the only one.

Maintenance vaccination by the health services

At the conclusion of their mass vaccination campaigns, most countries planned for continuing programmes of maintenance vaccination to be provided by the existing health services. Health units were requested to ensure the vaccination of newborn infants

and of children at health clinics and at school entry and to undertake periodic community-wide vaccination campaigns, but the outcome was seldom satisfactory. In all countries, large numbers of people visited health units daily for treatment but the opportunity was rarely taken to vaccinate them. When health centres were inspected, vaccine was regularly found which had been reconstituted days or even weeks previously and continued in use even though stored without refrigeration. Many of the vaccinations performed were probably unsuccessful but in few centres were subjects checked to see what the results had been.

After the mass campaigns, the levels of vaccinial immunity declined steadily in almost all countries, as was documented during surveys conducted for certification purposes. Although not the intention, this proved, paradoxically, to be helpful in the certification process; with large numbers of susceptible persons, smallpox, if present, was more likely to spread and to be detected than it would in a well-vaccinated population.

Assessment

The WHO Handbook called for "a programme of continuing evaluation of coverage and vaccination take rates by an assessment agent (or team) who is administratively independent of the vaccination team". What was envisaged was a random sample survey of 10–25% of those vaccinated, to be conducted 1–4 weeks after mass vaccination had been completed in an area. The use of an assessor who reported to someone other than the vaccination team leader increased confidence in the reliability of the findings. Although other useful types of evaluation were proposed in the WHO Handbook and were used subsequently in the programme, an ongoing appraisal of this type provided the most important information for use in the quality control of the campaigns. Like surveillance, however, sample assessment was unknown to most health officials and was adopted only with reluctance. Most considered it wasteful of manpower and vehicles to create a team whose sole responsibility was to check the work of others. Many were more willing to provide sufficient personnel to re-examine the entire population and vaccinate those without vaccination scars, but this was rarely feasible or cost-effective.

Independent assessment, although not universally practised, was used to good effect in assembly-point programmes in Brazil and in a number of African countries, as well as in the house-to-house vaccination campaign in Afghanistan. The rationale of the methods and standards deserves comment. For a reasonably accurate appraisal of the quality of work in an area to be made, a random selection of villages was important, however crudely done, otherwise the assessment teams would visit the villages that were most easily accessible by vehicle and therefore the most likely to have the best vaccination coverage. The methods used for random selection varied widely, from a sophisticated approach in Guinea, in which villages were selected within a defined sampling frame and in proportion to population, to a much simpler one in Afghanistan, in which pieces of paper bearing the names of villages in which vaccination had been performed were placed in a box and the specified number drawn at random. The method of sampling was less important, however, than the fact that sampling was done and that teams were aware that their work was regularly checked and that, if the results were unsatisfactory, more work would be required. Most took pride in being able to meet or surpass the established goals.

The assessment teams also evaluated the efficacy of the vaccine that had been used, but only in the case of primary vaccination. The primary vaccination lesion was so distinctive that there was never any question whether vaccination had or had not been successful. With revaccination, on the other hand, there were many equivocal responses among persons with partial immunity, and their interpretation differed from observer to observer. Moreover, a standard for successful revaccination was impossible to establish because of the varying levels of immunity in different areas. For primary vaccination, a successful take rate of at least 95% was established as a minimum standard, a figure which permitted a margin of error in recording and observation because take rates normally approached 100% when a satisfactory vaccine was properly applied. The assessment of results of primary vaccination only had the further advantage that the response could be evaluated 1–4 weeks after administration, rather than in the 6–8 day period required to evaluate revaccination responses. More flexible schedules for the assessment teams were thus possible. In all but a few instances, primary vaccination take rates consistently exceeded 95%; where they were found to be

lower, problems of vaccine handling or vaccine quality were usually discovered which could then be rectified.

Coverage after a campaign was measured in terms of the proportion of the population with a vaccination scar or with evidence of recent primary vaccination rather than in terms of the proportion vaccinated during the campaign. It was simpler and more reliable to inspect a person, particularly a child, for the presence or absence of a vaccination scar or lesion than to ask whether the subject had been vaccinated during the team's visit. This simplified method was feasible because vaccinial immunity was so durable in endemic areas, even after a single primary vaccination. The standard of performance originally set by the WHO Handbook was that not less than 80% of the population should show evidence of immunity, as indicated by a vaccination scar. In most programmes, levels of 90% or more were common, the highest rates being among adults and older children. With time the methodology was changed so that in most countries only children under 15 years or even under 5 years were examined, but the criterion was retained that not less than 80%, and sometimes 90%, of that age group should have a vaccination scar or lesion. This approach was operationally advantageous because children were more likely than adults to be found in or near their homes when a visit was conducted. Given that older age groups consistently had even higher levels of coverage than the younger ones, a standard requiring evidence of immunity in 80% of children effectively ensured an overall population immunity of more than 90%.

The assessment data provided information on performance, but they were also used to guide operations, which was just as important. When it was found that vaccination coverage was below standard, teams were usually required to return to the area, sometimes without the payment of travel allowances, to revaccinate the entire population.

Other forms of assessment were also employed in the mass vaccination campaigns. One, used almost everywhere, was to compare the number of vaccinations performed in an area with the estimated resident population. This provided a rough indication of the success of the campaign but an unreliable one because the available population data for small localities were often highly erroneous and often many non-residents were also vaccinated. In some areas of western Nigeria, for example, where the number of vaccinations reported to have been performed corresponded to 80% of the population, sample surveys later showed that fewer than 40% had vaccination scars.

Another approach was to enter the names of all residents and their vaccination status in a register (as in India) or on cards (as in Zaire), in the expectation that, after the vaccination team had left, health staff could refer to the records and vaccinate those who had been missed. The preparation of such records, however, was exceedingly time-consuming; keeping them up to date proved all but impossible; and the effort required to find and to vaccinate every person who had been missed was prohibitive. All countries which endeavoured to register the names of vaccinated subjects soon abandoned the practice as being impracticable except the United Republic of Tanzania. There, what were called "ten-cell chairmen" prepared a list of all the inhabitants of their assigned area and, when vaccination teams arrived, called individuals forward one by one for vaccination. There were few countries, however, in which political or other organizations could assume such a burden of clerical work, and even in the United Republic of Tanzania the information was not retained as a permanent record.

Sample surveys to assess the status of immunity of selected population groups were undertaken periodically in a number of programmes. Such surveys proved useful for deciding on vaccination strategies for special groups and, on a larger scale, were important when it came to certifying the absence of smallpox. National and other large-scale surveys were performed in western Africa and in India but they proved of little value. National and, in Nigeria, regional surveys, conducted in western Africa in 1969–1970 to measure overall programme performance, revealed problems in some areas, but the information was obtained so long after the campaign had been conducted that the specific causes of the problems could not be identified nor corrective measures taken (see Chapter 17). In India, the forms and assessment methodology used in Afghanistan (see Chapter 14, Plate 14.3) were introduced in some states. It was hoped that health officers responsible for the house-to-house vaccination campaign would identify areas and

populations which had not been well vaccinated and would take corrective action. Although tens of millions of people were examined in the course of assessment exercises, most health officers saw the activity as an end in itself and took no action to correct problems. Large-scale surveys of this kind were gradually abandoned.

Progress in national programmes had traditionally been measured by the numbers of vaccinations reported each year. The data, compiled by administrative units, continued to be collected throughout the course of the programme but varied considerably in quality. In most areas, the vaccinations actually performed were counted, but in some, the numbers reported were equivalent to the assigned goals, while in others, they were estimated on the basis of the quantity of vaccine used. As the programme progressed, these data received less and less attention and greater emphasis was placed on trends in the numbers of reported cases of smallpox. By the early 1970s, data on the numbers of vaccinations reported each year and in each country ceased to be compiled in Geneva and, by the mid-1970s, interest in them was largely confined to the media, which regularly inquired about the numbers of vaccinations being performed. It proved preferable to give the reporters some estimate than to attempt to explain why such data were no longer available.

Legislation

Legislation on smallpox and vaccination existed or was adopted in most countries, but in most instances it proved to be of little benefit other than as an official statement of policy. In the majority of countries, legislation was enacted which called for compulsory vaccination at or shortly after birth, periodic revaccination, and the mandatory isolation of patients; some countries prohibited variolation and required citizens to report cases of smallpox. On the few occasions when action was taken to enforce such laws, the results were poor and often counterproductive. In India, for example, attempts to levy fines on persons who refused to be vaccinated led to protracted proceedings in the courts without any apparent increase in compliance by the general public. The forcible isolation of patients in hospital often caused many families to hide infected household members and impeded effective containment measures. The prohibition of variolation may have caused some variolators to abandon the practice but in Afghanistan, for example, it resulted in the general public refusing to supply information about them, making it more difficult to identify them and to persuade them to cease their activities.

Other forms of coercion, however, were occasionally needed and effective in special circumstances. For example, in crowded refugee camps, the rule that all persons should be vaccinated before being given food ensured rapid and complete coverage; during containment vaccination, a police presence often discouraged resistance to vaccination; and in Botswana the government's threat to expel a religious group from the country secured cooperation in accepting vaccination when other measures had failed.

The Surveillance–Containment Strategy

The history and rationale of the surveillance–containment strategy have been described earlier, as has its implementation at the global level. At the national level, the foundation for implementing the strategy was the network of reporting posts making up the national reporting system, complemented by mechanisms for the prompt investigation of cases and the containment of outbreaks. The WHO Handbook stressed the importance of establishing or strengthening a reporting network from the inception of each national programme but postulated that, in countries with a high incidence of smallpox, the available resources would not immediately permit the investigation and containment of all outbreaks. Although the Handbook recommended that a reporting system should be established in all countries as soon as possible, it proposed that, in countries reporting more than 5 cases per 100 000 population, case investigation should be limited to major outbreaks and to those in areas in which mass vaccination had been completed. In other countries, all cases were expected to be investigated and containment measures taken. In mid-1967, the data available showed that only 13 of the 31 countries in which smallpox was then endemic had rates of 5 per 100 000 or more, of which 6 were in western Africa (Dahomey (Benin), Mali, Niger, Nigeria, Sierra Leone and Togo), 4 in eastern and southern Africa (Burundi, Uganda, United

Republic of Tanzania, and Zaire) and 3 in Asia (India, Indonesia and Pakistan).

The belief that it would be some time before all reported cases could be investigated and contained rested essentially on 3 premises which, in most of the endemic countries, proved to be incorrect. The first was the notion that the level of vaccinial immunity in the population was universally low, especially in countries with a high smallpox incidence, and that mass vaccination would be necessary before the numbers of cases decreased sufficiently to permit each to be investigated. Overall vaccinial immunity in some countries was indeed low and mass vaccination campaigns did serve to reduce incidence, notably in Afghanistan, Brazil, Ethiopia, Nepal, northern Nigeria and Sierra Leone. In 1967, however, half or more of the population of most countries were found to have vaccination scars, and among these countries were some which reported a substantial proportion of all cases. In India, Indonesia and Pakistan, more than three-quarters were already fully or partially immune because of past disease or prior vaccination. It was found there that the interruption of smallpox transmission was less closely related to an increase in the proportion of the total population with vaccinial immunity than to better reporting and containment measures. The second misconception was that, where smallpox incidence was high, cases would be so numerous and widely scattered that a great many teams would be required to investigate and contain the outbreaks. With few exceptions, it was discovered that smallpox cases, although far more numerous than reported, were clustered in comparatively small areas, so that relatively few surveillance teams were needed to investigate and contain them. Finally, it was believed that, in most countries, health units were so few and so scattered that reporting systems would have to be based primarily on reports from village leaders, teachers and the like, and that these systems would require considerable time and substantial manpower to establish. In fact, most countries, even many of the least developed in Africa, had a remarkably extensive network of health posts and far larger numbers of health personnel than the WHO Smallpox Eradication unit had expected.

Soon after the Intensified Programme began, it became apparent that surveillance–containment programmes could be developed reasonably quickly and that such systems could rapidly interrupt transmission. The findings in East and West Pakistan in the years 1965–1968, in eastern Nigeria in 1967 and in Tamil Nadu State (India) in 1968 showed that:

(1) The reporting of cases, although incomplete, was usually adequate to identify most large outbreaks; many other cases could be readily discovered by a few field teams through the investigation of reported cases and by questioning health staff and villagers.

(2) Patients with smallpox usually transmitted the disease to very few people and only to those in close face-to-face contact. Transmission in markets or schools, for example, was uncommon. Outbreaks therefore tended to be clustered among acquaintances in certain parts of a city or areas of the country rather than being widely and randomly dispersed.

(3) Only persons with a rash were able to transmit infection to others; this made it comparatively simple to trace the chain of transmission from person to person.

(4) Where, as was the case in most countries, there was significant seasonal fluctuation in smallpox incidence, few persons or villages were infected during the season when transmission was at a low level; the discovery and containment of outbreaks during this season substantially reduced the number of cases in the subsequent smallpox season.

(5) Outbreaks could be easily and rapidly contained in most areas with a high degree of success by isolating the patient and vaccinating contacts and most persons in the immediate vicinity.

Given also that smallpox was so distinctive that it could be diagnosed reasonably accurately by villagers themselves, that there was an incubation period of fully 10–12 days between cases, and that the vaccine provided more durable protection than had been believed, the conditions for an effective surveillance–containment programme were unusually favourable.

Nevertheless, however logical and attractive the surveillance–containment strategy appeared to be, it was not readily accepted by programme directors. In part, the difficulty lay in understanding and accepting what seemed to be a simple concept—that all cases of smallpox were links in an identifiable continuing chain of infection and that, in every area, there was a finite, usually small

Plate 10.28. Careful questioning of villagers could usually reveal the source of infection of the first case in an outbreak of smallpox, but it was not always easy to tell from their directions where and how far away the person concerned might be.

number of chains. If a 2-week interval between cases is assumed, a single chain of transmission in a country would result in not less than 25–50 related cases in the course of a year. Even in countries with many cases, the number of chains of infection would not be large; a country with 500 cases a year would have no more than 10–20 such chains. Because the cases were so closely related to one another, the strategy required not only the containment of each outbreak but also the discovery of the antecedent cases and outbreaks in the chain and their containment. The lack of comprehension of this principle during the early years of the programme was indicated by the frequent reference by many programme directors to the occurrence of "sporadic" cases rather than to cases whose source of infection could not be found.

At the outset it was difficult to convince the authorities of the usefulness of setting up surveillance teams staffed by competent senior health personnel, although many created "fire-fighting teams" of poorly supervised vaccinators whose task was to administer vaccine when epidemics were discovered. Even when demonstration programmes were conducted by its most enthusiastic proponents, the surveillance–containment strategy was slow to gain acceptance. In western and central Africa, Dr William Foege and his colleagues tried to introduce it from the summer of 1968 but, as is recounted in Chapter 17, northern Nigeria, the most heavily infected area, did not participate. In 1968 and 1969, Dr A. R. Rao enthusiastically described his successful experience in interrupting transmission in Tamil Nadu State (see Chapter 15), but he did not succeed in persuading other state programme directors in India to follow his example; in Brazil, the achievements in 1969 of Dr Ciro de Quadros and his colleagues were likewise disregarded (see Chapter 12). Precisely when country-wide surveillance–containment programmes were fully implemented is difficult to say, but approximations are possible for the most populous countries. In the endemic countries, the first were those in western and central Africa, which began late in 1968. These were followed by Afghanistan and Indonesia in 1969, East Pakistan in 1970, Brazil, Ethiopia and Zaire in 1971, Botswana and the Sudan in 1972, India, Nepal and Pakistan in 1973, and Somalia in 1977.

Before 1973, simple surveillance–containment measures were employed, and these are described first in the following sections. From 1973 onwards, with global eradication closer and more resources available, the techniques became increasingly sophisticated; that period is discussed later in this chapter.

Routine notification of cases

The foundation of the surveillance system was a weekly report from each health unit which documented the number of smallpox cases seen that week; if none was found, a report showing "nil" had to be sent. To simplify and encourage reporting, only the most basic facts about the patients were requested: name, age, sex, village (or urban district), date of onset of rash, and whether the patient had previously been successfully vaccinated (as shown by the presence of a scar). The information could be contained in one line on a form and the report was therefore termed a "line listing of cases". These reports were to be dispatched at the end of the week to an intermediate administrative

unit (a state or province in smaller countries, a district in larger ones) and so on up the echelons, eventually reaching the national programme office. Each week, the national office reported to WHO Headquarters by telex or by mail the number of cases of smallpox by week of report and by district and state or province.

The system was designed to provide only the information that was relevant to programme operation at each administrative level. To check that the system was operating correctly, all units at each administrative level were expected to submit a report whether or not cases of smallpox had been detected. Numbers of deaths were not requested because progress in the programme was monitored in terms of smallpox incidence; the action to be taken, such as investigation and containment, was related to the occurrence of cases rather than of deaths. The information provided by the line listing, which was necessary for the investigation of cases by the surveillance teams, was of the greatest value at state or provincial offices in smaller countries or district offices in the larger ones. To facilitate the transmission of data by telegram or telex, higher-level administrative authorities received current data only on the numbers of cases by administrative unit. More detailed epidemiological information was usually collected and analysed nationally, but at a later stage.

In the notification system, all cases, irrespective of date of onset, were supposed to be recorded according to the week in which they were detected. In most countries, this meant the week in which they were seen by the health unit. A record system of this type was simple to operate and worked far better than one in which an attempt was made to record and tabulate all cases according to week of onset of illness.

In 1967, reporting practices varied widely from country to country; none followed precisely the pattern described above, but many had a reporting structure by which each health unit provided some sort of report weekly or monthly. This often entailed notifying cases of 25–50 diseases together with a variety of data on the operations of the health units. The reports were seldom used for operational or supervisory purposes and efforts were rarely made to ensure that they were submitted promptly or even that all units reported. At intermediate administrative levels, the situation was little different. Special notification systems were sometimes prescribed for the diseases subject to international quarantine regulations, such as smallpox. Some required village leaders and others who became aware of a case of the disease to report it to the responsible administrative authorities, but this was seldom done. Telex or telephone notification of the quarantinable diseases to national or provincial authorities was also requested in some countries but, again, not consistently carried out. With smallpox, there were other problems. Some health units diagnosed mild cases as "variola minor", considering them not to be "true smallpox", and did not report them. Where, as in India, the occurrence of cases was taken as evidence by supervisors that the vaccination campaign had been inadequate, health units suppressed reports of cases. In all countries, there was such substantial underreporting that it is not surprising that many countries believed smallpox to be a much less serious problem than it was.

The development of fully satisfactory notification networks took not less than 1–2 years. In many countries, this was facilitated by epidemiologists or mobile surveillance teams, each of which could usually cover an administrative area with a population of 5–10 million. The teams regularly visited each health unit to explain the programme, emphasize the need to report cases, encourage vaccination, distribute forms and vaccine, and check on late reporting. When cases were reported, the team investigated and contained the outbreaks, sometimes with the help of those at the health unit, and usually discovered many additional cases in the process. The frequent visits to the health units by the mobile teams and their prompt response when cases were reported proved to be a great stimulus to reporting, especially because other supervisory health staff rarely visited health units. Interest was also stimulated by national surveillance reports, published weekly or monthly in many countries and distributed to health staff at all levels.

Of the many problems encountered in developing the notification network, two deserve mention because of their relevance to the development of systems for other diseases. The first was the difficulty of persuading health authorities of the need to receive regular weekly reports, even when no cases were found. Most assumed that if no report was received, no cases had been detected. Experience showed, however, that the units

that failed to submit reports were usually the least effective in performing functions of all types, including vaccination. It was in such areas that large, hitherto unknown epidemics were the most frequently discovered. The second problem, encountered only in India, related to the decision by government authorities to record all cases according to week of onset rather than week of report. This resulted in chaotic record-keeping at all levels of the health system and contributed to a significant underreporting of cases (see Chapter 15).

Reporting units, even in the smallest countries, numbered 100 or more, and in countries with large populations, more than 1000. In India, the largest of the endemic countries, there were no fewer than 8167 units reporting weekly to 397 district offices, which, in turn, reported to 31 state programme offices, and these to the national programme office in New Delhi.

Other mechanisms for case detection

Routine case notification by health units, however assiduous, provided only incomplete data on numbers of cases. While such data were useful when deciding on the allocation of resources and as a point of departure for field investigations, additional measures were required to detect most and eventually all existing cases. For various reasons, patients did not always go to health units: some lived too far away; many, especially with variola minor, were not sufficiently ill to seek medical attention; some believed, rightly, that therapy would be of little value; and some wished to avoid detection so as to escape, for religious or cultural reasons, compulsory hospitalization or vaccination of household contacts. Not surprisingly, few patients came to health units in areas in which their dwellings were burnt as a prophylactic measure.

Help in detecting cases was sought from other health staff as well as from the government and private individuals. Health workers who moved from village to village in the course of family planning, malaria, leprosy or yaws control programmes should have been a useful source of information, but few contributed significantly until a reward was offered for detecting cases of smallpox. At different times and in different countries, appeals to report suspected smallpox cases were also made to administrative officials, religious leaders, development officers, agricultural extension workers and police and security forces; although many were helpful in other ways, their assistance in reporting on smallpox was minimal.

The most effective mechanism for detecting cases not seen at health units was the field investigation of the cases which had been reported. This was usually one of the first measures to be undertaken as surveillance programmes developed. Because the spread of smallpox tended to be limited to close personal contacts, many additional cases could usually be quickly discovered among the family and village or neighbourhood contacts of a case. By careful questioning of the patients, sources of infection in other villages could be identified and investigated. In Brazil, for example, the investigation of each reported case brought to light an average of 50 other cases.

As the Intensified Smallpox Eradication Programme progressed, it became apparent that the discovery of cases through routine reporting and the investigation of outbreaks were still inadequate. Many outbreaks were large by the time they were found and had already spread to other areas. Monthly or semi-monthly visits to all villages would have served to detect cases earlier, but in most countries it would have taken a year or more to visit every village, even briefly, given the number of the smallpox eradication staff.

Methods were therefore required to permit the staff to search rapidly for cases over wide areas. Among the first of the methods developed were inquiries by workers in schools and markets. Schoolchildren proved to be an exceptionally good source of information, being well informed as to who in their villages was ill and with what diseases and tending to be more forthcoming with information than adults. Surveillance teams were able, in a brief visit to a school, to question children from villages as distant as 5–10 kilometres. This approach, developed in Indonesia in 1969 (see Chapter 13), eventually became standard practice in all surveillance programmes. Akin to this approach was the questioning of those attending weekly markets.

When the numbers of outbreaks in a country or area decreased to very low levels, it became possible to search for cases among those who had been exposed to patients but had left the area. Tracing such contacts was difficult and not especially productive: com-

paratively few contacts became ill, since many were already immune or had not been sufficiently exposed to become infected. This technique was seldom used, therefore, even when there were few outbreaks.

The techniques for case detection described above were adequate for programmes in most countries of Africa and South America as well as some in Asia, but in the densely populated areas of Asia additional measures were adopted. Village-by-village and even house-to-house search became possible when additional staff could be recruited. The first village-by-village search was conducted in Indonesia in 1969 and the technique was employed thereafter in high-risk areas (see Chapter 13). It began to be used in India in 1972 and was extended nationally in 1973 (see Chapter 15). It then became the standard practice in the remaining endemic countries.

Data analysis and surveillance reports

Important elements of the surveillance process, as described in the WHO Handbook, were "the concurrent analysis and interpretation of reported data and studies" and the "widespread dissemination of the compiled and interpreted data to principal reporting sources and to others concerned with disease control activities". Although such activities might appear to be logical and routine in any systematic data collection process, they were uncommon at first in the endemic countries. This reflected, in part, the fact that progress in smallpox programmes had been measured by numbers of reported vaccinations rather than by numbers of cases of smallpox, and, in part, the disdain commonly felt by health officials for routinely collected morbidity data, which are everywhere recognized to be incomplete. Rather than using the information that was available, while at the same time trying to improve the system, such officials took little notice of the data.

Routinely collected morbidity data, incomplete and biased though they may have been, proved of value from the beginning of the programme and, as they improved, became ever more useful. Vaccination campaigns in most countries began in the areas that reported the largest number of cases and, in some, smallpox was eliminated before the national campaign came to an end. When cases were found primarily among children less than 15 years of age, the campaign strategy was altered to focus particularly on the vaccination of children. The early observation that most cases of smallpox occurred among persons who had never been vaccinated led to the studies previously mentioned which showed that vaccinial immunity was far more long-lasting than had been appreciated and to a consequent emphasis on primary vaccination. Many other illustrations of the usefulness of morbidity data could be offered.

In addition to the international surveillance reports, already described, national surveillance reports were also prepared and had a major impact on the various programmes. The first of these was a weekly mimeographed report, which was started in Brazil in 1967 (see Chapter 12). When special surveillance teams began discovering large numbers of unreported cases, it described what appeared to be a developing epidemic and this in turn attracted the attention of the press together with renewed political commitment and increased resources.

Containment

The containment of an outbreak was, in principle, straightforward, calling for isolation of the patient, vaccination of the members of his household and other contacts, investigations to determine if there were other cases in the area and identification of the source of the outbreak so that it, too, could be investigated and contained.

Before 1967, the responsibility for, and the methods used in, investigating and containing outbreaks differed from country to country. In most, local health officers were expected to initiate the necessary control measures, although national vaccination teams were sometimes deployed. Where variola major was present, mass vaccination was widely used when large outbreaks occurred, but smaller outbreaks were usually ignored. Special measures were seldom taken against the mild variola minor form. Patients usually remained in their homes or, where hospitals existed, were confined to a smallpox ward or a general infectious diseases ward. Special investigations to identify all cases or to determine the source of infection were practically unknown. If the patient recovered, it was sometimes the practice to disinfect surfaces in the room by scrubbing them with a formalin solution or carbolic soap and to burn the patient's clothing and bedding. In some places the practice was to